

# Procedural Sedation for Infants, Children, and Adolescents

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American Academy of Pediatrics

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# **Procedural Sedation for Infants, Children, and Adolescents**



**Section on Anesthesiology and Pain Medicine  
American Academy of Pediatrics**

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To those who care for and comfort children.

*You hold my hand, your pace is slow.*

*You give me time for my stride to grow.*

*I follow you and learn your ways.*

*You teach me how to walk my days.*

*Your steps are big, mine are small.*

*We stroll together, through it all.*

*Take my hand, don't let go.*

*But hold it loose, to let me grow.*

—Anonymous

To my wife, Julie, and my boys, Drew and Michael, who inspire, guide,  
and love me unconditionally; buddies forever.

—Joseph D. Tobias, MD, FAAP

To my family—who have taught me everything I know about love  
and humanity, in all aspects of life.

—Joseph P. Cravero, MD, FAAP



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## Foreword

In 1983, in response to a number of adverse events in children sedated for dental procedures, the American Academy of Pediatrics (AAP) asked its Committee on Drugs and Section on Anesthesiology (now known as Section on Anesthesiology and Pain Medicine) to develop sedation guidelines; with the input from many different specialties, the first-ever sedation guideline was born. The concepts of safe sedation practices were adopted by The Joint Commission, which subsequently required hospitals to develop unified sedation policies for each institution. Similar specialty-specific sedation guidelines were later developed by the American Society of Anesthesiologists, the American Academy of Pediatric Dentistry, the American College of Emergency Physicians, and multiple international organizations.

Over the years, the AAP sedation guideline has undergone a number of revisions; each time, additional safety initiatives were added based on the available literature and expert opinion. The Pediatric Sedation Research Consortium, a collaborative group of institutions and highly motivated practitioners from many specialties, began collecting safety and outcomes data during and following procedural sedation. Data from more than 300,000 children have been collected, analyzed, and published, improving science and contributing evidence-based medicine for sedation practices. This professional manual, *Procedural Sedation for Infants, Children, and Adolescents*, in many ways is a blend of the safety net and guidance from the AAP sedation guidelines and all the hard work of the sedation consortium. Twelve well-written and concise chapters, authored by experts from a variety of backgrounds and specialties, take the reader through the steps needed to provide safe sedation.

The approach presented in this manual for procedural sedation is much like the approach to children undergoing general anesthesia: pre-sedation evaluation and a focused airway assessment, informed consent, appropriate regard for fasting and important safeguards when a procedure is urgent and proper fasting is not possible, functioning age- and size-appropriate equipment, equipment checklists, detailed understanding of the pharmacology and pharmacodynamics of drugs administered for sedation, proper monitoring during (hopefully including expired carbon dioxide monitoring) and after the procedure, continuous quality improvement efforts, simulation of rare events, and appropriate staffing, monitoring, and recovery procedures.

Congratulations to all who have contributed to this professional manual and for those of you who will benefit from reading it. Thank you for working so diligently to make the sedation process safer and less threatening to children. It is most rewarding to see how safe sedation practices have evolved, and I am honored to have been asked to write this foreword.

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## Preface

Procedures, both invasive and noninvasive, remain a common and necessary component in the management of children with acute and chronic diseases. Over the years, we have witnessed a shift in philosophies with an increased recognition of the potential short- and long-term effects of performing procedures in children without adequate sedation and analgesia. Parents and patients alike often view invasive procedures as worse than the disease itself. In the past, sedation was reserved for the “bad children” who would not hold still for a procedure and fought the health care practitioners who were restraining them. Given this change in perspective, children are being more appropriately managed, resulting in less trauma and improved outcomes.

The need to perform sedation effectively and safely has been recognized by many credentialing and professional organizations with the production of multiple guidelines to guide practitioners in the development of appropriate processes and strategies for procedures. We are thrilled to partner with the American Academy of Pediatrics on the production of this manual, *Procedural Sedation for Infants, Children, and Adolescents*. The intent of this manual is to provide critical information on the major aspects of procedural sedation. We are proud to have partnered with pediatric subspecialists and health care practitioners from a variety of specialties in pediatrics in the production of this manual. Rather than being exclusive, we believe that the safe provision of effective sedation for our patients must be inclusive with the input and cooperation of practitioners from various arenas. It is hoped that this cooperative effort will add to the ever-increasing excellence that we are achieving with procedural sedation. Most importantly, we hope that we will improve the care we provide our patients and ensure their safety.

Joseph D. Tobias, MD, FAAP

Joseph P. Cravero, MD, FAAP

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## CHAPTER 1

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# **Pediatric Sedation: The Past, Present, and Future**

*Joseph P. Cravero, MD, FAAP*

## **Introduction**



The provision of effective and safe sedation for children undergoing tests and procedures outside of the operating room remains a critically important part of the scope of pediatric health care. This area of care has been a dynamic and evolving field of practice for children. Many aspects of sedation are still in a state of flux.

1. The scope of practice for physicians other than anesthesiologists is evolving to include the use of potent sedative and hypnotic agents. Many formal sedation services are now run by a range of pediatric subspecialists.<sup>1</sup>
2. Monitoring technology is changing and improving. Specifically, monitors for end-tidal carbon dioxide and depth of sedation are becoming widely available at a relatively low cost and are being used with greater frequency as part of routine procedural sedation care.<sup>2</sup>
3. Discussion continues about the best methods to describe depth of sedation and nomenclature concerning the levels of sedation, particularly that produced by ketamine.<sup>3,4</sup>
4. Training, credentialing, and oversight of those who deliver this care have likewise undergone study and seen the incorporation of patient simulation into training for and credentialing of procedural sedation.<sup>5,6</sup>

This chapter will begin with a review of the history of pediatric procedural sedation through an evaluation of the guidelines that have been written for this care by the American Academy of Pediatrics (AAP) and other organizations. The future of pediatric sedation will also be discussed, along with

some strategies that have been used to set up efficient, effective, and safe sedation services.

## The History of Procedural Sedation

### Guidelines

The history of pediatric sedation is not well documented in the peer-reviewed literature. The practice of sedating children involves pediatric-oriented physicians from a variety of specialties, pediatric dentists, anesthesiologists (adult and pediatric), nurse practitioners, registered nurses, and child life specialists. As such, the progress and development of this area of pediatric care is fractionated among a large number of journals and conferences. It is not neatly “contained” in any one professional area of study. On the other hand, children have always required anesthesia and sedation for a variety of procedures. It is obvious to any pediatric health care practitioner that children may require sedation for procedures that otherwise healthy adults routinely tolerate while awake (eg, magnetic resonance imaging [MRI], routine filling of dental caries). As medical technology exploded in the 1970s and 1980s (including computed tomography and MRI), the requirement for sedation of children increased. Recognizing the growing number of pediatric procedures requiring sedation outside of the traditional operating room setting and responding to several deaths attributed to sedation in dental offices and beyond, the AAP first established sedation guidelines in 1985.<sup>7</sup> This first monitoring guideline was authored by the AAP Committee on Drugs, which included Charles J. Coté, MD, and Theodore Striker, MD, who were members of the AAP Section on Anesthesiology. It emphasized concepts that had been well established as promoting safety in the field of anesthesiology. The guidelines outlined a systematic approach to providing sedation care. They addressed the need for informed consent, appropriate fasting intervals, regular charting of vital signs, the availability of age- and size-appropriate equipment, the use of physiologic monitoring, the need for basic life support skills, and proper recovery and discharge procedures. As had been accepted in anesthesia care, the concept of an independent observer whose only responsibility was to monitor the patient was introduced for deeply sedated pediatric patients. These guidelines also addressed the environment and

equipment needs for sedation, as well as basic information on the various drug interactions that can affect the safety of sedation. The original guidelines defined 3 terms for depth of sedation: *conscious sedation*, *deep sedation*, and *general anesthesia*. These terms became ingrained in the lexicon of sedation provision for children, and subsequent iterations of these guidelines have sought to refine and improve these categories. The guidelines immediately affected sedation provision for children when the general recommendations were endorsed by major organizations such as the American Society of Anesthesiologists (ASA) and (ultimately) The Joint Commission.

In 1992, the AAP Committee on Drugs (primary author, Dr Coté) revised the 1985 guideline.<sup>8</sup> The revised statement was careful to point out how a patient could readily progress from a given level of sedation to another without warning. It also emphasized that the practitioner should be prepared to increase vigilance and level of monitoring if a deeper level of sedation is attained. Pulse oximetry was widely available and recommended for all patients undergoing sedation. This revised statement took a strong stance against the practice of administering sedation at home (by parents) prior to arrival at the hospital, which had previously been routine in many institutions.

Another amendment to this guideline was produced in 2002.<sup>9</sup> Perhaps most importantly, this time, the use of the term *conscious sedation* (and its inherent contradiction in terms) was eliminated in favor of *moderate sedation*. The guideline now unified the terminology used for levels of sedation as *minimal sedation*, *moderate sedation*, *deep sedation*, and *general anesthesia*. This terminology is still accepted by the AAP, American Academy of Pediatric Dentistry (AAPD), ASA, and The Joint Commission.<sup>10</sup> Finally, the authors also clarified that these guidelines apply to any location where children are sedated, in or out of the hospital, including dental offices and similar free-standing locations.

The most recent version of the guideline, published in 2006, further exemplifies the historical progress made in sedation delivery for children.<sup>11</sup> Given the increased use of potent sedation agents such as propofol and dexmedetomidine, the guideline requires that the sophistication of monitoring and the skills of the sedation practitioner must match the level of sedation. It moved the field closer to using the term *procedural sedation* to encompass the entire spectrum of level of sedation in the pediatric population. By doing this, it unified the approach so that all patients receiving any type of sedative



agent for procedures would undergo the same evaluation, preparation, monitoring, and recovery for the agent(s) used. A practitioner with advanced airway skills should be readily available for all sedations and present in the room for deep sedations so as to be able to rescue the child if native airway reflexes and tone are lost or attenuated. The routine use of capnography was “encouraged” because this technology had become widely available and proven beneficial in the anesthesia operating room environment. Finally, the guideline stressed the importance of recent advances in human simulation for training sedation practitioners and collection of quality improvement data.

Other organizations, including the American College of Emergency Physicians (ACEP), have written their own practice guidelines and advisories for sedation. The American College of Emergency Physicians has written multiple versions of an evidence-based guideline for sedation drug utilization in the emergency setting<sup>12</sup> and also published a nil per os (NPO) guideline that includes considerably shorter intervals than those advocated by the AAP and ASA.<sup>13</sup> Given the nature of emergency department practice and the data that have been published from emergency medicine specialists, these NPO recommendations are graded based on the urgency of the procedure and the targeted level of sedation for a given patient. Finally, ACEP has proposed that ketamine sedation should be considered outside of the sedation spectrum described by the AAP in a category of “dissociative sedation.”<sup>14</sup> The evolution of these guidelines has served as a timeline for the development of sedation as a major part of the training and expertise in the specialty field of pediatric emergency medicine.

Publication of the AAP/AAPD and ACEP guidelines exemplifies the progress made over the last 40 years in providing safe and effective sedation for children. This field has progressed from one with few standardized definitions, guidelines, or protocols to one in which excellence in training, monitoring, and record keeping are consistent and widespread. There is good evidence that safety of elective sedation for children is excellent when practiced in organized sedation services with serious adverse events occurring on the order of one in tens of thousands of encounters.<sup>14</sup> To achieve this performance, it is important for sedation practitioners to be familiar with the policies and regulations of the institutions in which they work. It is imperative to abide by those interpretations of the available guidelines and evidence.

## Sentinel Events

No review of the history of pediatric sedation would be complete without the inclusion of some of the sentinel reports that have influenced the development of this field. Published studies in pediatric sedation have traditionally evaluated relatively small groups of patients receiving specific drug combinations for sedation in a single institution. While collectively they have formed the basis of our current practice, few have individually changed the nature of sedation practice. Distinct exceptions to this generalization are 2 papers by Coté et al published in *Pediatrics* in 2000.<sup>15,16</sup> These reports had 4 sedation experts review sedation mishaps reported to the US Food and Drug Administration and the US Pharmacopeia Convention as well as a survey of specialists. One hundred and eighteen events were identified, of which there was agreement among the experts on causes for adverse outcomes in 95 cases. Of these, 51 resulted in death, 9 in permanent neurologic injury, 21 in prolonged hospitalization, and 14 in no harm. The first paper looked at the settings and circumstances in which these events occurred. Results pointed clearly to the fact that serious adverse outcomes were associated with sedation in nonhospital settings. Rescue capability was highlighted as a key factor in determining outcomes. The use of appropriate monitoring (specifically pulse oximetry) was associated with better outcomes. The second of these reports evaluated the medications used in the critical incidents mentioned in the first report. In this analysis, no specific medication class was associated with an increased frequency of events; rather, as expected, an overdose of any specific medication or combinations of medications (particularly 3 or more) was associated with increased frequency of adverse outcomes. Taken together, these papers had a profound effect on the provision of sedation for children. Most importantly, they highlighted the potential risk associated with pediatric sedation. In addition, they initiated focus on improving safety by providing appropriate rescue systems, the need for appropriate monitoring, and sensible protocols for medication administration.

## The Current Need for Procedural Sedation and Its Future

At present, there are limited national data on the current need for pediatric sedation and how that relates to the availability of sedation services. The 35 institutions participating in the Pediatric Sedation Research Consortium (PSRC) all report that there is difficulty meeting the total number of requests for sedation and often a waiting time of several weeks for routine MRI simply based on availability of sedation services.<sup>17</sup> The requirement for pediatric sedation is almost certain to increase in the future for multiple reasons.

1. Medical technology continues to evolve and expand. The further development of MRI technology (and indications for its use), positron emission tomography scans, endoscopy techniques, and all types of interventional radiology procedures raise the expectation that the requirement for procedural sedation or general anesthesia for pediatric patients undergoing testing and minimally invasive treatments will increase in the future.
2. Growing emphasis on keeping medical costs under control will (logically) put pressure on practitioners to find efficient and cost-effective methods for accomplishing technology-intensive tests and procedures in children. Where it is safe and possible, medical systems will seek to move these procedures from an operating room environment to areas outside the operating room, where sedation replaces traditional anesthesia care.
3. An appreciation of the long-term effects of untreated pain and stress on children has placed an emphasis on providing appropriate sedation for children undergoing all types of interventional procedures.<sup>18</sup> At the same time, there is concern about the effect of general anesthesia on the neurocognitive development of infants.<sup>19</sup> The result will likely be continued requests for sedation care that is of high quality, safe, and effective while potentially avoiding general anesthesia where it is not absolutely needed.

## Setting Up a Procedural Sedation Program

There is no doubt that the trend in pediatric sedation in the United States is toward the formation of specialty services that provide pediatric sedation. Sedation services are not a new concept; they have been shown to improve sedation outcomes for children for the last 20 years.<sup>20</sup> More recently, the PSRC has recorded more than 300,000 sedation encounters, all of which were derived from elective pediatric sedation services in hospitals across the United States and Canada. Results from this research collaboration have shown a very high degree of safety and an outstanding rate of successful procedure completion, which exceeds 99%. The specialties of the practitioners who staff and organize pediatric sedation services include pediatric anesthesiologists, emergency medicine physicians, intensive care physicians, and a growing cadre of pediatric generalists (hospitalists).<sup>21–24</sup> Sedation systems also vary in their organization. Some are located in a sedation unit, while others travel to the various locations that require procedural sedation for children.<sup>25</sup> Safe, effective, and efficient sedation services for children require a coordinated microsystem within a hospital or medical center. This system understands the needs of its customers and has the leadership and support to meet these needs.<sup>26</sup> Despite the variety of practitioners and processes involved, these systems have several critical aspects in common.

1. They are directed by individuals who have a strong desire to see pediatric sedation delivered in the most safe, effective, and efficient manner possible.
2. There is focus on improving the process of sedation for children throughout the hospital or medical center where they are located. These services must be valued by the other pediatric practitioners in the institutions in which they exist and they must have appropriate resources allocated. This implies appropriate space, personnel, monitoring equipment, and medication delivery systems that are critical to the delivery of sedation.
3. These systems exist as teams in which pediatric sedation nurse input is valued and strongly encouraged. In addition, successful systems almost always include individuals who are particularly expert in non-pharmacologic interventions, such as child life specialists or play therapists. These individuals are also well equipped to help manage the emotional and behavioral stresses that accompany sedation for procedures in the child *and* family.

4. Most successful systems are supported by and work with anesthesiology departments in their institutions, with multidisciplinary input from various other departments and divisions, including pediatric intensive care unit physicians, emergency department physicians, and hospitalists. Protocols for triage of particularly difficult patients and the presence of backup support are critical to the smooth running and safety of sedation services.
5. Strong sedation services are flexible. They have enough staff to manage the inevitable add-on procedures (for a given patient) and the add-on patients (for a schedule), which will always be a part of procedural sedation work flow.
6. Excellent sedation services participate in ongoing quality improvement efforts and respond to areas of concern or unmet need in a timely fashion.
7. Efficient sedation services have an administrative infrastructure that allows organized scheduling for the various procedures that require sedation within their institution. Scheduling ideally allows for blocks of time to be used by various departments, such as hematology/oncology, radiology, and urology.

The aspects discussed herein represent the professionalization of pediatric sedation and have seen this area of practice evolve from one in which many individuals dabbled to one in which growing specialization has led to a subgroup of pediatric specialists working within well-supported systems with a focus on sedation as a primary area of interest and expertise.

## Summary

The delivery of sedation to children has a rich history and an intriguing future. The past 30 years have seen vast improvements in the safety and effectiveness of pediatric sedation through the development of guidelines for care and the incorporation of advanced techniques, improvements in monitoring methods, and guidelines for post-procedure care. The future will undoubtedly see an increase in the need for high-quality sedation given developments in other areas of pediatrics. This need will be best met by a diverse group of practitioners primarily working in organized sedation services using advances in pharmacology and technology.

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## CHAPTER 2

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# The Pre-sedation Evaluation

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### Introduction



During the past 10 to 15 years, there has been a considerable shift in philosophy about pediatric procedural sedation, with an increasing recognition of the negative aspects of performing painful or stressful procedures in awake children or with inadequate sedation. Therefore, there has been an increased need for the provision of sedation for such procedures. Furthermore, deeper depths of sedation are used and the scope of practitioners performing sedations has widened. Given this expansion of procedural sedation services, there is an increasing need to assess and improve these practices. One of the key components in such practice is the pre-sedation evaluation.<sup>1-3</sup> Adverse airway, hemodynamic, or respiratory effects represent the primary causes of morbidity and mortality associated with procedural sedation.<sup>4</sup> The first step in the prevention of such problems is appropriately identifying the at-risk population, which can be accomplished during the pre-sedation evaluation.<sup>5</sup>

The importance of this aspect of sedation care is now recognized and should be included as a key component of the procedural sedation process. In many centers, the current practice of pre-sedation evaluation and preparation of the patient for procedural sedation parallels that of the preoperative evaluation. As with other aspects of procedural sedation (including monitoring and practitioner training), the pre-sedation evaluation should be the same regardless of the anticipated depth of sedation. Current guidelines from the American Academy of Pediatrics (AAP), the American Society of Anesthesiologists (ASA), and The Joint Commission direct that the safety of patients is best maintained by approaching all patients undergoing moderate or deep sedation as a single concept and not differentiating between the proposed depths of sedation with respect to evaluation or preparation.



This chapter will review key components of the pre-sedation evaluation, including the airway examination, and discuss the effect of some of the more common comorbid disease processes encountered in the pediatric patient. Another key component of the pre-sedation evaluation is the nil per os (NPO) time, which is discussed herein and in Chapter 3. One of the key purposes of the pre-sedation evaluation is not only to prepare the patient for the sedation experience but also to identify those patients with comorbid or acute conditions that may preclude the use of procedural sedation. In specific scenarios involving significant systemic illnesses or airway abnormalities, patients may be more appropriately cared for by pediatric anesthesiologists.

## Pre-sedation Assessment

Once it has been determined that a patient requires sedation, a pre-sedation assessment should be performed or scheduled. The goals of the assessment include

1. Determining that the patient is medically fit to be sedated. Assessment of this fitness is divided into 2 components: identification of acute illnesses that may increase the likelihood of complications during sedation and identification of comorbid conditions that may require specific interventions during sedation or place the patient at a sufficiently high risk for adverse effects that procedural sedation cannot be accomplished. In some of these circumstances, the patient should be referred to a pediatric anesthesiologist. An example of such a patient may be one with critical congenital heart disease (eg, palliated hypoplastic left heart syndrome) or a documented or suspected difficult airway.
2. Using the assessment to allow the practitioner to determine the depth of sedation that will likely be required to effectively complete the procedure and make an informed decision about the agents to be used. This may also include assessment of the duration of the procedure. Prolonged procedures (>90 minutes) or those requiring a totally unresponsive patient (general anesthesia) may also be considered for referral to a pediatric anesthesiologist depending on the experience and expertise of the procedural sedation team. Ideally, this assessment should be performed by the individual who will ultimately be providing the sedation. This ensures that the person providing the sedation has firsthand knowledge of the

patient and his or her medical needs. It also allows the practitioner performing the sedation to address specific patient concerns prior to the sedation and continue to focus on these issues while the actual procedure is being performed.

3. Providing an opportunity to educate and inform parents about how procedural sedation is accomplished and options available to the patient. Additional issues regarding parental instructions and informed consent are discussed in Chapter 3.
4. Discussing the eventual disposition of the patient. Will inpatient admission be needed? Is a monitored bed needed given associated comorbid conditions?
5. Determining the need for additional workup or expert consultation prior to the sedation event.
6. Determining if additional medications are required prior to the sedation event. These may include agents to decrease gastric contents or increase pH or albuterol and ipratropium to prevent bronchospasm.

The entire pre-sedation history, evaluation, and examination should be performed in all but the most emergent procedures. Even in the emergent setting, key information can be obtained quickly as the patient is transported and prepared for the procedure. The ASA emphasizes that evaluation of the airway “should be conducted, whenever feasible, prior to the initiation of anesthetic care and airway management in all patients.”<sup>3</sup> The key information can be obtained within minutes using a focused history and physical examination, the suggested components of which are outlined in Box 2-1. The history should focus on the child’s current state of health as it relates to the reason why the procedure is required, acute ongoing processes, and past medical history to identify significant comorbid conditions.

An example of an acute illness that may affect the procedural sedation process is an intercurrent upper respiratory infection (URI). In the past, it had been recommended that anesthetic care be delayed for up to 6 to 8 weeks following a URI given the risk of increased respiratory events (eg, bronchospasm, laryngospasm, oxygen desaturation) in these patients. However, it is currently recognized that many children will have recurrent URIs during the first 2 to 6 years of life. Therefore, it may not be feasible to wait 6 to 8 weeks after each URI, as there may never be a period of complete health between

**Box 2-1. Components of the Pre-sedation Assessment**

1. Demographic data: patient's name, age, weight, and gender
2. Past medical history
  - a. Comorbid medical conditions
  - b. Acute medical conditions
  - c. Previous sedation and anesthetic history
3. Allergies
4. Current medications
5. Family history of anesthetic complications
  - a. History of malignant hyperthermia or high postoperative fever
  - b. Prolonged paralysis following procedures using NMBA
6. Dietary history (NPO status)
7. Social history
  - a. Tobacco or illicit drug use
  - b. Exposure to secondhand tobacco smoke
8. Perceived urgency for the procedure
9. Pregnancy history
  - a. Routine pregnancy screening may be indicated based on institutional guidelines.
10. Physical examination
  - a. Baseline vital signs including room air oxygen saturation
  - b. Airway examination
  - c. Cardiac and pulmonary examination
11. Laboratory evaluation (if appropriate)
12. Summary
  - a. ASA status
  - b. Plan
  - c. Risks discussed and informed consent obtained

Abbreviations: ASA, American Society of Anesthesiologists; NMBA, neuromuscular blocking agents; NPO, nil per os (nothing by mouth).

these recurrent URIs. Likewise, in an urgent or emergent situation, it may be necessary to proceed with procedural sedation despite an acute infectious process.

## Physical Examination and History

### Airway

Although the history and physical examination are generally focused on the airway, heart, and lungs, at least a cursory examination and review of other systems should be performed. History and examination of the airway include

a history of prior anesthetic care, which may provide information about the airway. Was the patient's trachea intubated for the procedure or were there problems? The head and neck examination is also used to identify the patient in whom endotracheal intubation or bag-valve-mask ventilation may be difficult or impossible to perform. Although a native airway is generally maintained during the procedural sedation process, apnea and upper airway obstruction remain 2 of the primary problems associated with administration of sedative and analgesic agents. As such, interventions may be required to relieve upper airway obstruction, or bag-valve-mask ventilation may be required during apnea. Furthermore, upper airway obstruction may be more common in the presence of upper airway issues such as obstructive sleep apnea (OSA) or micrognathia. Problematic management of the pediatric airway, defined as difficulties with mask ventilation or endotracheal intubation, is rare. Poor visualization of the glottis or laryngeal inlet during direct laryngoscopy, defined as a Cormack and Lehane view greater than or equal to grade 3 (Table 2-1), occurs in approximately 1 in every 100 to 200 cases.<sup>6-8</sup> Although the incidence may be higher in patients with associated congenital heart disease undergoing cardiac surgery, many of these patients were noted to be associated with specific syndromes that, in themselves, are known risk factors.<sup>9,10</sup> Butler et al contains an in-depth review of various syndromes and their potential effect on airway anatomy.<sup>10</sup> The incidence of airway problems may be higher when airway management is performed outside of the operating room setting, eg, in the intensive care unit (ICU) or emergency department.<sup>11,12</sup>

Examples of phenotypic features that may impede airway management include a short neck, limited neck mobility, micrognathia, macroglossia, or limited mouth opening. Although validated only in the adult population, a more objective measure of the airway commonly used by anesthesiologists

**Table 2-1. Cormack and Lehane Scale**

<b>Class</b>	<b>Airway View</b>
Grade 1	Full view of glottis
Grade 2	Only posterior commissure is visible.
Grade 3	Only the tip of epiglottis is visible.
Grade 4	No glottis structure is visible.

Adapted from: Cormack RS, Lehane J. Difficult tracheal intubation in obstetrics. *Anaesthesia*. 1984; 39(11):1105-1111. © 1984 The Association of Anaesthetists of Gt Britain and Ireland, by permission of Wiley-Blackwell.

is the Mallampati scoring system (Table 2-2). If the patient is Mallampati class 3 or 4 (tonsillar pillars and uvula cannot be visualized), endotracheal intubation or effective bag-valve-mask ventilation may be difficult or even impossible. While the possibility of a difficult airway does not preclude the use of procedural sedation, anesthesiology consultation or backup may be considered prior to sedation.

Table 2-2. The Mallampati Scoring System

Class	Anatomic Features Visualized
Class 1	Complete visualization of the soft palate, uvula, and tonsillar pillars
Class 2	Complete visualization of the soft palate with partial visualization of the uvula and tonsillar pillars
Class 3	Visualization of only the base of the uvula and the soft palate. No visualization of the distal uvula or tonsillar pillars.
Class 4	No visualization of the soft palate, uvula, or tonsillar pillars

Derived from: Mallampati SR, Gatt SP, Gugino LD, et al. A clinical sign to predict difficult tracheal intubation: a prospective study. *Can Anaesth Soc J.* 1985;32(4):429–434.

Unfortunately, no single screening test (or even compilation of tests) has the needed sensitivity and specificity to be universally applicable for identification of potential airway issues. Most formulas and screening tests were developed for the adult population; when used in clinical practice, it becomes readily apparent that they are not all readily transferable to the pediatric patient. In a retrospective review of 11,219 general anesthesia procedures over a 5-year period in pediatric patients, the overall incidence of difficult laryngoscopy (defined as a Cormack and Lehane grade 3 or 4 view) was 1.35%.<sup>6</sup> Risk factors included age younger than 1 year (4.7% versus 0.7%), ASA class 3 and 4 (Table 2-3), a higher Mallampati class (3 and 4), a lower body mass index (BMI), and patients undergoing oral and maxillofacial surgery or cardiac surgery. For comparison, the same authors reviewed the anesthetic care of 102,305 adult cases and reported that the overall rate of difficult laryngoscopy was 4.9%.<sup>13</sup> Risk factors included male gender, Mallampati class 3 and 4, obesity with a BMI greater than or equal to 35 kg/m<sup>2</sup>, and ASA class 3 or 4. Again, they noted that specific surgical procedures were also identifying factors, with a higher incidence of difficult laryngoscopy noted in patients undergoing oral and maxillofacial; ear, nose, and throat; and cardiac surgery.

**Table 2-3. American Society of Anesthesiologists Physical Status Classification System**

ASA Class <sup>a</sup>	Description
1	No underlying medical problems
2	Mild systemic illness (well-controlled asthma, corrected CHD)
3	Severe systemic illness (sickle cell disease, severe asthma, uncorrected CHD)
4	Severe systemic illness that is a constant threat to life (uncorrected cyanotic CHD)
5	Patient is unlikely to survive 24 hours with or without the procedure.

Abbreviations: ASA, American Society of Anesthesiologists; CHD, congenital heart disease.

<sup>a</sup>An E is added for an emergency procedure.

Adapted from: ASA Physical Status Classification System of the American Society of Anesthesiologists, by permission of ASA. A copy of the full text can be obtained from ASA, 1061 American Lane, Schaumburg, Illinois 60173.

One final scoring system that merits mention, given its frequent use and validity in the adult population, is the Wilson risk score (Table 2-4).<sup>14</sup> A total of 3 or more of the features outlined in Table 2-4 predicted 75% of difficult laryngoscopies, while 4 or more predicted 90% in the adult population. There is a current trend toward combining various scoring systems or physical features in an attempt to improve specificity and sensitivity of these systems, especially in the pediatric patient.<sup>15</sup>

**Table 2-4. Wilson Risk Score for Difficult Endotracheal Intubation<sup>a</sup>**

Risk Factor	0	1	2
Weight	<90 kg	90–110 kg	>110 kg
Head and neck movement	>90 degrees	Approximately 90 degrees	<90 degrees
Jaw movement	Incisor gap >5 cm and subluxation >0	Incisor gap <5 cm and subluxation = 0	Incisor gap <5 cm and subluxation <0
Receding mandible	Normal	Moderate	Severe
Buck teeth	Normal	Moderate	Severe

<sup>a</sup>Score of 3 or more predicts 75% of difficult endotracheal intubations; score of 4 or more predicts 90%.

Adapted from: Wilson ME, Spiegelhalter D, Robertson JA, Lesser P. Predicting difficult intubation. *Br J Anaesth*.1988;61(2):211–216, by permission of Oxford University Press.

In addition to the features outlined previously, specific phenotypic features have been shown to be associated with difficulties with airway management. Many of these impede alignment of the structures required for endotracheal intubation, including the oral, pharyngeal, and glottic openings (Table 2-5). As noted previously and reviewed by Butler et al,<sup>10</sup> various congenital anomalies and genetic syndromes have been reported to result in difficulties with airway management. An additional physical feature that may alert the practitioner to the potential for a difficult airway is an abnormal external ear.<sup>16</sup> However, the risk seems to be particularly high when there is bilateral microtia.

Prior to the sedation event, a complete upper airway assessment should be performed, including obtaining a history of OSA or snoring and examining the head and neck. History of OSA is significant not only because of its potential association with difficulties in airway management but also because of the potential for upper airway obstruction following the administration of sedative agents.<sup>17,18</sup> These patients may also have altered  $\mu$  opioid receptors with increased sensitivity to the analgesic and respiratory effects of opioids. Physical examination of the airway is designed to identify phenotypic findings that may suggest that endotracheal intubation may be more difficult

**Table 2-5. Physical Features Suggestive of a Difficult Airway**

Physical Feature	Clinical Finding
Length of upper incisors	Relatively long
Relation of maxillary and mandibular incisors during normal closure	Overbite with maxillary incisors anterior to mandibular incisors
Relation of maxillary and mandibular incisors during voluntary protrusion of mandible	Cannot bring mandibular incisors in front of maxillary incisors
Inter-incisor distance	<3 cm (adult) or <2 finger breadths <sup>a</sup>
Visibility of uvula	Mallampati class 3 or 4
Shape of the palate	Highly arched or narrow
Size or integrity of the submandibular space	Small or indurated, firm or mass present
Thyromental distance	<3 cm (adult) or <3 finger breadths <sup>a</sup>
Length of neck	Shorter length
Neck circumference	Larger neck circumference
Range of motion of head and neck	Limited flexion and extension

<sup>a</sup>For this evaluation in a child, use the patient's own fingers.

(eg, short neck or short thyromental distance, limited neck mobility, micrognathia, macroglossia, limited mouth opening or trismus). A commonly used measure is the Mallampati scoring system (see Table 2-2).

## Physical Examination and History

### Heart and Lungs

The other 2 major areas that require evaluation during the focused history and physical examination are the cardiovascular and respiratory systems. Although most children are free of comorbid disorders, there is a growing population of patients dependent on technology who have spent prolonged periods in ICUs who may have comorbid conditions that should be investigated prior to the procedure. While routine workup beyond the physical examination is unnecessary in most patients, those with preexisting cardiac disease, including congenital heart disease, or who have received potentially cardiotoxic chemotherapeutic agents should be seen by their cardiologist prior to any elective sedation event. An electrocardiogram, echocardiogram, and cardiology note should be available to determine the optimal regimen for sedation and the appropriate post-sedation disposition of the patient. Furthermore, a decision should be made about the need for antibiotic prophylaxis for endocarditis. Patients with pulmonary hypertension may be particularly tenuous during procedural sedation. In most instances, these patients are best cared for by pediatric cardiac anesthesiologists given the high incidence of perioperative and peri-sedation adverse events.<sup>19,20</sup> These patients may prove refractory to resuscitation efforts should adverse events lead to cardiac arrest.

In specific clinical scenarios, preoperative pulmonary function testing (PFT) may be indicated. Although generally more of a concern for patients undergoing general anesthesia, PFT may be used to stratify the sedation risk and therefore differentiate when the patient requires referral to a pediatric anesthesiologist. These issues are of primary concern in patients with baseline PFT below 30% to 40% predicted for age. An algorithm for the perioperative respiratory care of these patients has been outlined by the American College of Chest Physicians consensus statement on the respiratory and related management of patients with Duchenne muscular dystrophy undergoing



anesthesia or sedation.<sup>21</sup> The panel recommended the preoperative measurement of the patient's oxygen saturation in room air using pulse oximetry ( $\text{SaO}_2$ ). Measurement of the partial pressure of carbon dioxide using a blood gas analysis or end-tidal carbon dioxide is recommended when  $\text{SaO}_2$  is less than 95% in room air.<sup>22</sup> The presence of hypercapnia ( $\text{PaCO}_2 \geq 48\text{--}50$  mm Hg) should prompt further evaluation and discussion with a pediatric anesthesiologist or care by an experienced procedural sedation team. The panel also recommended measuring preoperative forced vital capacity (FVC) with the patient in a seated, upright position. These recommendations are partially based on work performed by Harper et al.<sup>23</sup> In their cohort of 45 patients, 20 had a preoperative FVC less than or equal to 30% predicted for age. The authors reported no statistically significant difference in the duration of postoperative endotracheal intubation, duration of support using noninvasive ventilation, total time with ventilator assistance, and inpatient stay. However, there were significant cardiorespiratory complications in both groups, demonstrating that this is a high-risk population with the potential for perioperative complications. Five of the 20 patients (25%) with an FVC less than or equal to 30% had complications, including adult respiratory distress syndrome (ARDS), respiratory tract infections, and the need for a tracheostomy, while 4 of the 25 patients (16%) with a preoperative FVC of 30% to 50% predicted for age had complications. The one death in the cohort was a patient with an FVC of 18% who initially had an uncomplicated postoperative course but went on to develop ARDS. The consensus panel from the American College of Chest Physicians used these data to provide a 2-level risk-assessment scale such that a preoperative FVC less than 50% is suggested to be predictive of an increased risk of perioperative complications, while there is a *high* risk if the preoperative FVC is less than 30% of that predicted. Another high-risk group to consider are patients on home noninvasive ventilation (bi-level positive airway pressure [BiPAP]) to treat OSA or chronic respiratory insufficiency. Although such patients may be a candidate for procedural sedation, which, if feasible, may be a safer alternative to general anesthesia, consultation with a pediatric anesthesiologist is suggested. In such patients, the BiPAP device may be used during and immediately after the sedation event.

Sedation practitioners may also be asked to evaluate and sedate patients with acute respiratory illnesses. In general, elective procedures requiring general anesthesia should be postponed for at least 2 weeks following the resolution

of symptoms from an acute illness. However, there are no data on which to base recommendations for procedural sedation. In the setting of acute URI, airway reactivity may lead to a higher incidence of bronchospasm, laryngospasm, or oxygen desaturation.<sup>24,25</sup> These problems are magnified in children exposed to secondhand tobacco smoke. Until further data are available, care should be individualized for each patient, with an assessment of the patient's current status, course of illness, and urgency of the procedure.

While routine pre-procedure chest radiographs are generally not indicated, they should be considered in patients with pertinent findings in the history or physical examination. This may include those with a history of wheezing if a previous film is not available or in patients with peripheral lesions (lymphadenopathy) presenting for biopsy. The latter may coexist with a mediastinal mass, which may compromise ventilation following sedation or general anesthesia.<sup>26</sup>

## **Previous Sedation Events, Past Medical History, and Medication Record**

During the pre-sedation assessment, it is important to review the patient's previous experiences with procedural sedation. This is helpful in identifying their effectiveness as well as the patient's perception of the experiences. Knowledge of previous bad experiences will help the practitioner in the selection of the specific sedative or analgesic agent and provide the opportunity to address specific patient concerns prior to entry into the procedure room. Identification of these concerns also enables the practitioner an opportunity to engage the patient and family in pre-sedation counseling in which the risks, benefits, and limitations of sedation and analgesia are discussed. This discussion should include a description of the agents chosen for use along with specific effects or behaviors the patient or parents may anticipate from the agents. Discussion of previous sedation experiences is particularly important for patients with autism spectrum disorder or developmental delays. Parents can often provide insight into specific situations that elicit stress or anxiety. They can also include information on comfort objects or particular songs or movies that are calming for their child.

Following the focused history and physical examination, the patient's current medication list and allergies are discussed. In addition to prescription medications, this should include specific questioning on the use of over-the-counter medications, including herbal medications. In most cases, medications should be administered despite the NPO mandates necessary for procedural sedation. As noted in the 2006 AAP guidelines, it is permissible for necessary medications to be taken with a sip of water on the day of the procedure.<sup>1</sup> One example of such is anticonvulsant medication because many patients are sensitive to minor changes in plasma concentrations. Failure to administer these medications may result in seizures within hours of the medication time. There are very few, if any, medications that must be withheld prior to a sedation event. In the adult population, agents that act through the renin-angiotensin system, including angiotensin-converting enzyme (ACE) inhibitors and angiotensin receptor blockers, are generally withheld the morning of surgery. Patients taking ACE inhibitors and angiotensin II receptor-blocking agents preoperatively have a higher incidence of hypotension, more profound hypotension, and decreased responsiveness to exogenous catecholamines.<sup>27,28</sup> Depending on the agents selected and depth of sedation required, it may be advisable to discuss withholding these agents the morning of the procedure. Such a decision is best made in consultation with the patient's cardiologist or nephrologist.

## Laboratory Evaluation

In most patients, especially those who are ASA class 1 or 2, no laboratory investigation may be required.<sup>29,30</sup> Other laboratory tests are dictated by the presence of comorbid conditions. In patients with a history of renal insufficiency or failure, renal function should be evaluated. Patients receiving diuretic or digoxin therapy may require an evaluation of electrolytes. A routine hemoglobin check is indicated in preterm infants who are less than 60 weeks' post-conceptual age, given the association of anemia (hemoglobin <10 g/dL) with apnea risk.<sup>31–34</sup> These preterm infants should also have continuous post-sedation cardiorespiratory monitoring for at least 8 to 12 hours following sedation.

Another area of ongoing controversy is the role of routine preoperative (sedation) pregnancy testing. Given the theoretical potential for anesthetic and sedative agents to be teratogenic and increase the frequency of spontaneous abortion, history should include specific questioning about the potential for pregnancy, including the patient's last menstrual cycle. In addition, many centers routinely obtain urinary pregnancy tests prior to any anesthetic or sedation event.<sup>35</sup>

An additional component of the pre-sedation assessment is establishment of the timing of last oral intake to decrease the possibility of aspiration if airway protective reflexes are lost. The ASA recommends that patients be NPO for 2 hours for clear liquids, 4 hours for human milk, and 6 hours for nonfatty solids or nonhuman milk prior to undergoing sedation for elective procedures. These guidelines have been increasingly challenged, particularly by those working in acute-care environments where procedures may need to be performed more urgently. While published reports from these environments have failed to show an effect of pre-procedure fasting on the incidence of adverse outcomes, these studies have been underpowered to truly evaluate this question. Until appropriately powered studies have adequately addressed this issue, it is prudent to adhere, as much as possible, to the ASA guidelines. In patients undergoing semi-emergent or emergent procedures who have not met the appropriate fasting guidelines, the use of H<sub>2</sub> receptor antagonist or promotility agents such as metoclopramide to decrease the volume and acidity of stomach contents should be considered. However, there is no evidence-based medicine to suggest their efficacy in preventing aspiration events during general anesthesia. Alternatively, the safest option in select patients requiring emergent procedural sedation may be the induction of general anesthesia with endotracheal intubation (rapid sequence intubation) to facilitate completion of the procedure and protect against aspiration.

## Summary

On completion of the pre-sedation evaluation, the cumulative information gathered should allow the practitioner to determine the depth of sedation that will likely be required to effectively complete the procedure and to make an informed decision about the agents to be used. During this time, the health care practitioner performing the procedure can also entertain

questions from parents, guardians, or patients and inform them of the usual conduct of the sedation and what to expect. If, during the pre-sedation assessment, it has been deemed unsafe to perform sedation, the patient should be referred to a pediatric anesthesiologist for further evaluation. An ASA classification should be assigned (see Table 2-3). Patients with ASA class 3 or 4 are at higher risk of adverse events when sedated, and pediatric anesthesiology consultation may be considered in these patients. In some elective cases, it may be determined that additional workup or consultation is necessary. Additionally, the pre-sedation assessment plays an important role in collecting information needed to appropriately inform patients and parents or guardians of the risks and benefits of the procedure. Some of these may have gone unnoticed or are unexpected by parents or guardians prior to the assessment. This information is useful because careful and complete informed consent conversations and documentation are essential to mitigating medical liability risk. Once all the information is gathered (including informed consent), the pre-sedation evaluation should be fully documented in writing or the electronic medical record.

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## CHAPTER 3

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# Documentation and Parental Instructions for Pediatric Sedation

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## Introduction



Documentation for sedation is as important as documentation during surgical anesthetic care and should meet the same standards. Children requiring sedation often return for additional procedures, and the sedation record can serve as an extremely valuable guide for future health care practitioners. The sedation record also serves as an excellent data repository for quality improvement efforts, especially if charted electronically in real time. The sedation record should include all components of the sedation experience, including the pre-sedation evaluation, actual sedation care documented in real time, and recovery phase.

When presenting for sedation care, parents may often not fully understand the risks associated with sedation. They may have misconceptions about how strictly fasting guidelines should be followed. Establishing reasonable expectations of the sedation process and providing parents with clear pre-sedation instructions will go a long way toward increasing parental compliance and improving patient safety. Additionally, effective communication may prevent unnecessary cancellations or delays in the sedation process. This chapter discusses these important components of procedural sedation. An outline of the suggested components of these integral steps in the sedation process is provided.



## Documentation for Sedation

Documentation is intended to give a clear impression of the conduct of the procedural sedation process, including the pre-sedation evaluation, intraoperative sedation events, and post-sedation recovery. It is meant to provide a clear record of the sedation encounter, including the medications administered; events that took place; the patient's response to the sedation, including vital signs and level of sedation; and the recovery phase. Given that many patients undergoing procedures requiring sedation will return for subsequent interventions, the record serves not only to document what occurred but also to provide valuable information for the next practitioner. For patients returning for frequent sedations, such as those undergoing daily sedation for radiation therapy, ready access to this information will streamline subsequent encounters by avoiding the need to ask repeated questions about the patient's past history and previous sedation encounters. Ready access to the pre-sedation evaluation allows it to be quickly updated rather than repeated from the beginning. Even for those patients requiring sedation at less frequent intervals, access to such information can significantly streamline the process.

Clear documentation will give future clinicians a better sense of what worked and what did not. A detailed record will also serve to indicate that appropriate standards of practice were followed and interventions implemented in a timely fashion should an adverse event occur. Electronic medical records (EMRs) can assist greatly in automating much of the data collection and recording process in quality improvement efforts. The use of EMRs increases the likelihood that needed information is readily available and not present in lost volumes or records.

### Pre-sedation Documentation

A pre-sedation patient evaluation should be conducted and documented. This documentation should include, but is not limited to, the patient's general state of health and functioning as well as key physical examination findings. Birth history should be briefly reviewed including gestational age, need for neonatal intensive care unit admission, and requirements for neonatal resuscitation, endotracheal intubation, or mechanical ventilation or support. A general review of systems should be conducted with particular

attention to the patient's cardiovascular and pulmonary status. The cardiac history should include any history of structural cardiac anomalies, dysrhythmias, syncopal events, or hemodynamic instability. A history of a dysmorphic syndrome should raise the level of suspicion that an associated cardiac malformation may exist as well. The pulmonary review should include any recent respiratory infection or chronic underlying respiratory disease such as asthma. Patients who have had upper respiratory infections (URIs) within the preceding 6 to 8 weeks may be at increased risk of increased airway reactivity, which can lead to laryngospasm or bronchospasm. This should be factored into the risk to benefit scenario when deciding whether to proceed with the procedure. Furthermore, because children may have as many as 6 to 8 URIs a year, it is generally not feasible to wait a full 6 to 8 weeks after a URI. An active or passive smoking history should be elicited, as tobacco smoke exposure increases airway reactivity.<sup>1</sup>

The physical examination should include a focused evaluation of the patient's airway in addition to cardiac and pulmonary examinations. In patients able to cooperate with the examination, the airway evaluation may include the Mallampati classification (see Chapter 2). The intraoral examination should include a note about the presence of any intraoral appliances as well as dentition, with missing or damaged teeth noted. Notation should be made of facial structure in all patients with emphasis on the presence of micrognathia or other anatomic problems that may complicate airway management. Cardiac examination documentation should include a description of heart tones, including the regularity of heart sounds and presence or absence of murmurs. Pulmonary examination documentation needs to include the clarity of breath sounds and whether or not they are equal bilaterally. Special attention should be paid to wheezing if present. In the case of patients with asthma, it is advised to document breath sounds after inhaler therapy if it is administered.

Other items that need to be documented on the pre-sedation evaluation include the patient's vital signs, fasting status, mental status, and weight. Vital signs should include oxygen saturation, heart rate, blood pressure, respiratory rate, and temperature. It is important to document the patient's pre-sedation mental status. Fasting status should be assessed and documented before sedation is started.<sup>2</sup>

Pregnancy testing has been and remains an area of controversy. Many surgical centers routinely obtain urine pregnancy tests on all post-menarche females and any female 12 years or older. The debate over whether to perform pregnancy testing arises because there has been doubt cast on the idea that sedation agents can lead to fetal harm.<sup>3</sup> We would encourage each center to develop its own policy to deal with this controversial aspect of procedural sedation.

Pre-sedation documentation should note that consent was obtained or counseling was performed and what was discussed about the sedation process. Pre-sedation consent and counseling should include the nature and purpose of the procedure for which sedation is being administered and the risks and benefits of the sedation method chosen. In an otherwise healthy patient without comorbid conditions, the risk of sedation may be virtually nonexistent. Although the risk of death related to general anesthesia is generally quoted as 0.1 to 0.2 per 10,000 anesthetics delivered, more recent data suggest that in the absence of serious comorbid conditions (ie, patients who are American Society of Anesthesiologists [ASA] class 1 and 2), the risk is virtually nil.<sup>4</sup> Although some practitioners do not even mention the risk of death given their desire to avoid upsetting parents, each individual practitioner must decide whether the risk of death should be mentioned during the pre-procedure discussion.<sup>4</sup> Available literature suggests that most parents of healthy children are already aware of the risk and would like to discuss it during the pre-anesthesia (pre-sedation) evaluation.<sup>5</sup> Some parents may believe that it is inappropriate to discuss the risk of death with children present. Obtaining consent and the specific risks discussed should be documented in the medical record.

The risk of sedation failure should be discussed and documented. If the procedure is such that sedation is not absolutely required, a note describing the patient's need for sedation due to anxiety or discomfort should be entered in the chart. For example, if the procedure in question is noninvasive and relatively fast (eg, computed tomography scan), many patients may not even require sedation. If the patient is too young or developmentally delayed to cooperate or has a comorbid condition that makes lying still for even a brief time difficult, sedation may be indicated. In these instances, it is important to note the reason for the sedation in the medical record. Alternatively, it may be appropriate to discuss with parents or guardians that there will be an attempt made to complete the procedure without sedation. If the patient

cannot tolerate this, he or she will receive sedation. This information will not only be of assistance to subsequent clinicians but may make billing easier and facilitate efficient completion of the intended procedure.

The sedation record should serve as a means of maintaining a high-quality and consistent experience for the patient and family. Patients who need to be sedated often require multiple procedures. In lieu of having the same sedation team care for the patient each time, the sedation record should be clear enough to allow different teams of clinicians to provide a similar experience for the patient and family. One key component is a notation of the type of premedication, if any, that was used and whether an intravenous (IV) cannula was placed prior to sedation delivery. Additionally, pre-sedation documentation can include a simple notation or check box that the appropriate resuscitation equipment, including medications, bag-valve-mask device, and suction, were assembled and readily available. This not only serves as a reminder to ensure that appropriate safety measures are followed but also provides needed documentation in the event of an adverse outcome.

## **Procedural Sedation Documentation**

The procedural sedation record serves not only as a required document but also provides essential information for future sedation practitioners. Although each institution will develop its own template for recording the sedation experience, consistent practices include a time-based record, which allows recording of vital signs and notation of medications used and dosages. In some institutions, a time-based record similar to one that is used intraoperatively is preferred. Regardless of the type of record that is used, key aspects of procedural sedation documentation include

1. Documentation that a time-out was performed prior to the start of sedation and the procedure. For example, in some practices, 2 time-outs are performed, one prior to the start of sedation with the nurse and the sedation practitioner present and one prior to the start of the procedure.
2. Medications administered, including route, dosage, and timing.
3. Airway adjuncts required, if any, including the use of supplemental oxygen and its method of delivery (face mask or cannula).

4. Vital signs, including oxygen saturation, heart rate, blood pressure, respiratory rate, end-tidal carbon dioxide, and temperature, recorded every 5 minutes. These can be record manually or automatically downloaded from monitors into an EMR.
5. Some measure of the adequacy and depth of sedation. This may include the use of a formal sedation scoring system as well as the response to the procedure. As with vital signs, this should be recorded every 5 minutes.

Documenting adequacy of sedation presents challenges in that depth of sedation is not simply a single, well-defined quantity like heart rate or oxygen saturation. Depth of sedation is a judgment by a clinician based on a number of criteria, which often involve a degree of interpretation. In the intensive care unit setting, some of the scales involve a tactile stimulus to the patient, especially if there is a need to differentiate between deeper depths of sedation. Such a practice is not recommended nor generally feasible during procedural sedation. One commonly used tool to evaluate depth of sedation is the University of Michigan Sedation Scale (UMSS), in which the clinician assigns the patient a sedation number from 0 to 4. In this scale, 0 reflects a patient who is awake and alert, while 4 indicates a patient who is unable to be aroused.<sup>6</sup> The full scale is outlined in Table 3-1. As outlined in the UMSS, differentiation between the 2 deepest levels of sedation (3 versus 4) requires tactile stimulation of the patient.

Another commonly used sedation measurement tool is the Richmond Agitation–Sedation Scale (RASS).<sup>7</sup> This scale allows for a greater spectrum of assessment than the UMSS in that it measures agitation as well as sedation.

**Table 3-1. University of Michigan Sedation Scale**

Score	Description
0	Awake and alert
1	Minimally sedated: tired/sleepy, appropriate response to verbal conversation and/or sound
2	Moderately sedated: somnolent/sleeping, easily aroused with light tactile stimulation or a simple verbal command
3	Deeply sedated: deep sleep, arouseable only with significant physical stimulation
4	Unarouseable

Reprinted from: Malviya S, Voepel-Lewis T, Tait AR, et al. Depth of sedation in children undergoing computed tomography: validity and reliability of the University of Michigan Sedation Scale (UMSS). *Br J Anesth*. 2002;88(2):241–245, by permission of Oxford University Press.

The RASS is well suited for intensive care patients and may be applicable in procedural sedation. The full scale is outlined in Table 3-2. Other sedation assessment tools that have been described in the literature include the Ramsay Scale and the Observer's Assessment of Alertness/Sedation. Whichever scale is used, there can be a degree of variability among users, so it is best to standardize the use of one particular tool at your institution. Patients who, at baseline, are somnolent or have diminished mental functioning can present a challenge in terms of defining a given level of sedation and recovery. In these cases, clinical judgment must be relied on, though it is important to note the patient's baseline to establish a frame of reference.<sup>8</sup>

Medications administered should indicate not only which agents were used but also the dose, route, and time of administration. The medical record should clearly show whether agents were given as boluses or infusions. The use of rescue medications (naloxone and flumazenil) needs to be clearly indicated because their use is often reviewed by the sedation committee or similar groups as part of the quality assurance process. The use of reversal agents generally mandates that the post-sedation observation period be extended to ensure that these agents do not wear off, resulting in re-sedation. The degree and nature of airway support required by a particular patient is important to document, as clinicians caring for the same patient in the future will benefit

**Table 3-2. Richmond Agitation–Sedation Scale**

Score	Term/Description
+4	Combative, violent, dangerous to staff or self
+3	Pulls or removes tube(s) or catheters; aggressive
+2	Frequent non-purposeful movement, fights ventilator
+1	Anxious, apprehensive, but not aggressive
0	Alert and calm
-1	Awakens to voice (eye opening/contact) >10 seconds
-2	Light sedation, briefly awakens to voice (eye opening/contact) <10 seconds
-3	Moderate sedation, movement or eye opening. No eye contact.
-4	Deep sedation, no response to voice, but movement or eye opening to physical stimulation
-5	Unarouseable, no response to voice or physical stimulation

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from knowing the level of support that was provided. Furthermore, changes in the plan that were necessitated by patient-related issues or adverse effects should be noted. This may include the need to add additional medications, the need for bag-valve-mask ventilation, or a sedation failure necessitating conversion to general anesthesia. Regardless of the type of form used, ample room for the addition of notes is suggested.

Vital signs are indicators of the patient's tolerance and response to the procedure and sedation. Sedation should be designed and administered with a desired end point in mind. Patients should receive enough of any sedating medication to allow them to tolerate the procedure without anxiety or discomfort while maintaining adequate oxygenation and ventilation with limited deviation from baseline vital signs. The vital signs obtained during any given procedure are an indication of how closely any particular sedation regimen met the goal. While heart rate, blood pressure, respiratory rate, and temperature are routinely documented, the importance of end-tidal carbon dioxide should not be overlooked, as it provides critical information about the patient's ventilation status. The youth and relative excellent health of many pediatric sedation patients may allow oxygenation to be maintained during periods of hypoventilation. End-tidal carbon dioxide monitoring provides another indication of appropriateness of the depth of a particular sedation regimen.<sup>9</sup> Documentation of these parameters allows subsequent clinicians to get a better sense of the patient's sedative requirements as well as his or her tolerance to the adverse respiratory and hemodynamic effects of the sedative or analgesic agents used.

## Post-sedation Documentation

Documentation of vital signs and emergence from the sedative regimen should be extended into the recovery period. Ongoing monitoring and documentation should be continued until the patient has returned to baseline status and is ready for discharge. Any complications that occur during the recovery phase, such as emergence agitation or nausea and vomiting, should be recorded. Post-sedation notation presents an excellent opportunity to provide the family and patient with a consistent or improved process during subsequent procedures. Post-sedation notes should include an indication of what worked, what did not, and how well the sedation regimen and procedure were tolerated by the patient. Inclusion of feedback from the patient or family should be considered as well. In the event that the person performing

the sedation is not the same person monitoring the patient's recovery, a formal handoff should be provided and documented in the medical record.

Prior to discharge, the patient's state of recovery should be noted and recorded using a standardized scoring system such as the Aldrete score,<sup>10</sup> which was developed for recovery from general anesthesia. The Aldrete score provides a number from 0 to 2 for the following components: respiration, oxygen saturation, blood pressure, consciousness, activity, and circulation (based on blood pressure). The maximum score is 10, while discharge is generally considered acceptable at a score of 9 or 10. The patient's state of hydration and ability to tolerate oral fluids are documented. The specific time of discharge should be recorded. It should be noted that specific discharge instructions have been given to parents, and in specific cases, these should be listed. Formal discharge orders and notes from the sedation practitioner should be included in the record. To facilitate the quality assurance process, it may be beneficial to use a standardized form that specifically outlines any adverse events that occurred during the process. These events can then be collected and subsequently reviewed to improve the sedation process.

## Parental Instructions

### General Instructions

Pre-sedation instructions are intended to maximize patient safety and alleviate family and patient anxiety. Additionally, effective pre-sedation communication will avoid unnecessary cancellations or delays in the sedation process. The family should be told when and what the child may eat before the procedure. Rather than just indicating that the child may have clear liquids, it may be better to give examples (eg, apple juice, Sprite, Pedialyte) to avoid confusion. The family should also receive information on the specifics of the procedure itself (eg, absence of metallic items for magnetic resonance imaging studies; bowel preparation for gastrointestinal procedures). Aside from teaching the specifics of the sedative or procedure, the family should be given a sense of the flow of the day. Logistic basics, such as where to park, where to check in, and where the family will wait, should not be overlooked. One frequently asked question or a source of anxiety for the child is how peripheral IV access will be obtained. Some of this anxiety may be alleviated



by discussing the usual routine of the sedation process. This may include answers to such question as

1. Will the child be awake when his or her IV is started?
2. Will a topical anesthetic cream be used?
3. Will an oral premedication be administered prior to IV access?
4. Is nitrous oxide generally used to facilitate IV placement?
5. How long will parents be allowed at their child's side, and will they be present for IV placement or even throughout the procedure?

The family should be asked to bring an extra set of clothes, including underwear, if appropriate, as this may make the ride home much more comfortable if the first set is soiled. A favorite toy or comfort item (eg, security blanket) should also be brought. Although this information can be provided over the phone or during a pre-sedation evaluation, it is likely to be more effectively delivered if these frequently asked questions are answered in a pamphlet that is provided to the parents.

Proper and consistent nil per os (NPO) or fasting instructions will go a long way toward increasing satisfaction and reducing frustration on the part of the family and sedation team by limiting patient discomfort. The ASA has developed guidelines for pre-anesthetic fasting (Table 3-3)<sup>2</sup> based on evidence when it is available and expert opinion in areas in which evidence is nonexistent or inconclusive. The guidelines allow for a great deal of flexibility on the part of the practitioner in terms of patient comorbidities such as diabetes or other conditions that may slow gastric emptying. Furthermore,

**Table 3-3. American Society of Anesthesiologists Nil Per Os Guidelines**

Food Type	Hours Prior to Sedation
Solid food containing fat	8
Solid food without fat	6
Nonhuman milk	6
Human milk	4
Clear liquids	2

Derived from: American Society of Anesthesiologists Committee on Standards and Practice Parameters. Practice guidelines for preoperative fasting and the use of pharmacologic agents to reduce the risk of pulmonary aspiration: application to healthy patients undergoing elective procedures: an updated report by the American Society of Anesthesiologists Committee on Standards and Practice Parameters. *Anesthesiology*. 2011;114(3):495–511.

based on the urgency of the procedure, these must be viewed as guidelines and not strict policies that reflect the standard of care. It should also be recognized that the American College of Emergency Physicians (ACEP) has questioned the utility of fasting in preventing adverse events during procedural sedation.<sup>11</sup> We would therefore encourage each institution to develop its own policies and procedures for procedural sedation, one aspect of which should be NPO guidelines.

Families and patients are done a great service when the fasting instructions they receive are clear and concrete. If one adheres to the guidelines of the American Academy of Pediatrics and ASA, it will reduce violations of the NPO status, which remains the primary reason for delaying or canceling procedures. Cancellations and delays decrease when NPO instructions are simple and permit little room for interpretation. A list of basic food types that are permitted and times at which particular food groups should be stopped is often better understood by families than a list of what should be avoided. For example, many families will be better off being told that their child may have dry toast until 6 hours prior to the sedation instead of being told that the child must avoid solid foods after that time. Asking the family to avoid nonfatty solids is only inviting well-intentioned NPO violations, as families may be unclear about what this means. Additionally, a list of allowable clear liquids should be reviewed with the family instead of merely saying that clear liquids are allowed up to 2 hours before the procedure. The importance of offering such fluids should be stressed, as this will facilitate IV access and lessen patient discomfort during prolonged NPO times. It is not uncommon for families to give their children broth prior to sedation. There are many variants of broth, some of which contain fat. Additionally, because some families may consider a thin soup containing solids as broth, there is much room for confusion. Given these concerns, it is recommended that patients avoid broth for at least 8 hours prior to the administration of a sedative medication.

Practitioners need to balance ease of instructions to facilitate compliance with the patient's volume status. Although it may be easier to ask that no food or drink be consumed after midnight, this may make the sedation process more difficult. Children, especially infants, do not tolerate prolonged periods of fasting well. Children who would otherwise be calm can become agitated when not permitted to eat or drink for many hours. Peripheral IV access can also be much more challenging in a relatively dehydrated child.

It has been suggested in the literature that hungry children with prolonged NPO times are more difficult to sedate.<sup>12</sup> All of this information should be reviewed with the parents at scheduling; during the pre-sedation evaluation, if this is performed prior to the day of the procedure; and the day before the procedure over the phone. One frequently encountered problem is the patient who arrives to the pre-sedation area chewing gum. This problem should be specifically addressed in the pre-sedation instructions with a notation that gum chewing is not allowed. There is some concern that gum chewing may lower gastric pH and therefore lead to increased risk of adverse outcome should the patient aspirate, even if the gum is not swallowed.<sup>13</sup> Some anesthesiologists therefore recommend that gum chewing stop at least 2 hours prior to sedation. Others are willing to proceed immediately as long as the gum is removed from the mouth and not swallowed. However, to avoid confusion and unnecessary delays, we recommend no gum chewing for 6 to 8 hours prior to the sedation event.

Families are more likely to comply with fasting instructions if they understand the rationale behind them. There are many misperceptions of the purpose of not eating prior to receiving sedation. Some parents, for example, believe that NPO guidelines exist simply for the purpose of reducing post-procedure nausea and vomiting. Even apparently clear directions are subject to misunderstanding.<sup>14</sup> Having the parent or guardian repeat the NPO instructions and rationale during the assessment may help in reducing compliance errors.

The purpose of minimizing gastric contents during the administration of sedating medications is to decrease harm to the patient should aspiration of gastric contents occur. It should be clearly pointed out to families that aspiration can be extremely dangerous; it can require endotracheal intubation for an extended period and can potentially be fatal. A common misperception of sedation is that it is simply a form of normal sleep. Families often feed their children just before a nap and they have seen no harm, so the risk of aspiration may seem very abstract. It is important to instruct families that sedation is different from normal sleep in that airway reflexes, which remain intact during sleep, are decreased or eliminated during sedation. The patient may be unable to protect his or her own airway during sedation, so it is incumbent on the family and practitioners to take on this responsibility themselves. Although the author's practice for procedural sedation is to adhere to the same NPO guidelines as the operating room, we appreciate that this is not

universal and outside of the purely elective procedural sedation scenario, strict NPO guidelines may not be practical. As noted previously, ACEP has questioned the need for strict NPO guidelines during procedural sedation, noting the lack of evidence-based medicine to demonstrate its efficacy.<sup>11</sup>

## Administration of Home Medications

Whether to continue or hold outpatient medications during the fasting period should be discussed with families as well. In general, significant morbidity can result if chronic medications are held versus limited risk when they are administered. Many families will assume that no medications can be given during the time that the patient cannot eat or drink. While specific instructions need to be individualized for each patient and clinical scenario, the following guidelines will apply in most cases. If medications are taken with small sips of clear fluid during the fasting period, patients are still considered to be NPO compliant. Problems may arise for children who cannot take medications with a sip of water but require the medication to be placed in a small amount of applesauce or pudding. When these issues arise, we believe that the best option is an individual assessment of that patient's particular needs and the risk to benefit ratio of the decision.

Patients with type 2 diabetes should generally withhold their insulin on the day of sedation. Patients with type 1 diabetes should hold short-acting insulin and take one-third of their long-acting insulin preparation. These patients will need to have their blood glucose levels checked on arrival and at least one more time prior to discharge depending on the length of the procedure or NPO period. Patients with insulin pumps should receive only their maintenance rate. Other anti-hyperglycemic agents, including metformin, should not be administered on the day of sedation. These patients will also require placement of an IV cannula and administration of a glucose-containing fluid until they have returned to their baseline state and are able to tolerate clear liquids.

Most other medications are continued throughout the sedation process. Although most antihypertensive medications should be administered, in the adult population, angiotensin-converting enzyme inhibitors and angiotensin-blocking agents are generally withheld the day of surgery due to the risks of hypotension following anesthetic induction.<sup>15</sup> This practice remains controversial in the pediatric patient and should be based on the institutional guidelines for general anesthesia and procedural sedation. Given

that large induction doses of sedative agents are not routinely administered during procedural sedation, such problems have not been reported.

In general, we would recommend that the administration of preoperative medication follow the same practice as used in the operating room of the hospital in question. We routinely administer most chronic medications, including those for gastroesophageal reflux, asthma, and birth control. Even in asymptomatic patients with asthma, we would suggest that parents administer albuterol the day of the procedure. Corticosteroids, immunosuppressive agents, and chronic opioid therapy can be continued during the sedation event. Decisions about nonsteroidal anti-inflammatory and other agents that affect coagulation function, including Coumadin, are based on the type of procedure involved. In patients receiving chronic anticoagulation medications, a discussion with their cardiologist or prescribing physician is recommended before these medications are withheld. For invasive procedures, specific instructions for herbal medications should be given to parents because of their potential effect on coagulation function.

## Electronic Medical Records

Electronic record keeping facilitates access to old medical records and allows for much easier data mining. Adverse outcomes are more easily identified, and analysis of what works versus what doesn't work in a large group of patients is facilitated. Once the practitioner has become facile with such tools, it may allow one to focus on the patient rather than data entry into a hard copy. As part of health care reform, the Health Information Technology for Economic and Clinical Health Act of 2009 encourages the use of EMRs. The intent of the act is to incentivize hospitals and clinicians via additional Medicaid and Medicare payments when EMR usage leads to improvements in patient care when "meaningful use" criteria are met.<sup>16</sup> Electronic medical record-keeping systems are available from a number of companies. Ease of use and network connectivity are key factors when selecting a system. The ability of any particular EMR to import data from and export data to a preexisting infrastructure is a vital consideration that should not be underestimated. In many institutions, although separate documents are used for procedural sedation and general anesthesia, the same system is used to facilitate transfer of data and communication between events.

## Summary

Documentation for procedural sedation and pre-sedation instructions are critical means of communication. The record of the sedative itself serves as a reference for health care practitioners who will administer sedation or anesthetics in the future. Pre-sedation instructions help parents or guardians to understand what the sedation entails and gives them the opportunity to participate in a safe outcome for their child. Clear documentation, especially when done electronically, also makes data review easier. This, in turn, provides more focus for quality improvement efforts. Areas needing attention can be more readily identified and problems addressed in a more efficient manner. Those parts of the process that work particularly well can be shared and replicated more accurately. Time and effort spent on a detailed record of the sedation process and thorough teaching for parents or guardians are an investment. The return on this investment is a good experience for patients today and a better experience for future patients.

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CHAPTER 4

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## Monitoring for Procedural Sedation

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### Introduction



Procedural sedation has become an essential part of adequately caring for children undergoing painful procedures or requiring prolonged periods of immobility (eg, magnetic resonance imaging [MRI]). While sedative medications target the conscious brain, they frequently adversely affect the respiratory, cardiovascular, and gastrointestinal systems. Most research focuses on the role of monitoring during sedation as a means to avert catastrophic events, but monitoring has the dual importance of clarifying a patient's response to sedation and the procedure.<sup>1,2</sup> This allows the clinician to respond quickly and appropriately to physiological changes and intervene early to prevent cardiorespiratory compromise. The literature has clearly demonstrated that one of the more frequent causes of adverse events remains inadequate monitoring of the patient during the sedation event. This monitoring should be initiated immediately at the start of the sedation procedure and continue until the patient has fully recovered from the event and has met discharge criteria. The importance of this aspect of procedural sedation is emphasized and covered in detail in procedural sedation guidelines from the American Academy of Pediatrics (AAP), American Society of Anesthesiologists (ASA), and American College of Emergency Physicians. The effective use of monitoring mandates that there be one health care practitioner whose only responsibility is to continuously monitor the patient and respond to physiological changes as indicated. This chapter reviews basic monitoring for procedural sedation, such as pulse oximetry, and discusses the potential applications of technologies being used more frequently,



including end-tidal carbon dioxide (ETCO<sub>2</sub>) monitoring, and of devices, such as the bispectral index (BIS), to assess the depth of sedation.

## Monitoring Technology

### Pulse Oximetry

Pulse oximetry is a simple to use and reliable monitor that provides a continuous estimation of the patient's oxygen saturation and is generally considered the single most helpful monitoring device for detecting impending life-threatening airway events.<sup>3–5</sup> Regardless of the agents used for procedural sedation, the final pathway in most adverse events is hypoxemia leading to eventual cardiac arrest. Not only does the pulse oximeter indicate hemoglobin oxygen saturation, but it also monitors the heart rate continuously and indirectly provides feedback on the presence of a perfusing rhythm via the plethysmograph. Pulse oximetry has been commercially available since 1983 and became a standard of care for anesthesia monitoring in the operating room in 1987. In 1992, the AAP recommended continuous quantitative pulse oximetry monitoring during procedural sedation.<sup>6</sup> In a single-blinded study of pulse oximetry in children in the operating room, patients who did not have pulse oximetry available experienced significant hypoxemia at more than twice the rate of monitored patients, and duration of hypoxemia lasted approximately 75% longer than monitored patients.<sup>7</sup>

Pulse oximetry measures hemoglobin oxygen saturation noninvasively via an external probe. Light of 2 wavelengths passes through the skin to a photodetector; the differential absorbance of these wavelengths by pulsating arterial blood is used to calculate oxygenation. While multiple biological processes may affect oxygenation, in the typical healthy patient undergoing procedural sedation, a decrease in pulse oximetry generally represents decreased oxygen availability to the body. This downstream effect may have resulted from a range of ventilatory complications, including hypoventilation, apnea, upper airway obstruction, or laryngospasm, thereby resulting in a prolonged duration of inadequate gas exchange prior to desaturation. How long it takes for a given patient to “desaturate” depends on multiple factors, including the oxygen reservoir capacity of the lungs, administration of supplemental oxygen, the patient's minute ventilation or metabolic needs, and

hemoglobin characteristics. Healthy adults breathing room air who experience apnea will experience an oxygen saturation drop to 85% in 1 minute.<sup>3</sup> Infants who have undergone preoxygenation with a non-rebreathing face mask will desaturate to 90% within 90 seconds, while healthy adolescent patients may take 6 to 7 minutes.<sup>4</sup>

The primary cause of morbidity associated with sedation or analgesia is drug-induced respiratory depression and airway obstruction. This can first be detected by capnography or continuous auscultation of breath sounds. If the ventilatory issues are not rapidly detected or resolved, respiratory depression will lead to oxygen desaturation detectable by pulse oximetry. The resulting hypoxemia during sedation is more likely detectable by pulse oximetry than clinical assessment alone.<sup>5</sup> In an analysis of 1,256 critical events occurring during general anesthesia, pulse oximetry detected the largest number of events first.<sup>2</sup> In a theoretical analysis, if pulse oximetry had been used on its own, it would have detected 82% of the incidents, with nearly 60% detected before any potential for organ damage.<sup>8</sup> In a separate analysis of adverse sedation events with a range of outcomes (death to no harm) performed prior to routine availability of capnographic monitoring, successful outcomes without injury or harm were associated with the use of pulse oximetry.<sup>9</sup>

Although motion artifact occurs less often with new-generation pulse oximeters, oximetry measurements are still susceptible to malpositioning, leading to artificially low saturation measurements in patients with normal blood levels of oxygen and occasionally higher than true values in patients with hypoxemia.<sup>10–12</sup> The latter is especially true in patients with cyanotic congenital heart disease because device accuracy may be reduced in the lower saturation range of these patients (75%–80%). Pulse oximeters that display plethysmography tracings are recommended to improve interpretation of numeric values and allow detection of poor signal quality.<sup>13</sup> Likewise, pulse oximeters that include an audible change in tone provide an early warning of desaturation for everyone in the room, regardless of whether the monitor is actively observed, and an extra safety margin during sedation. Use of an appropriate probe is essential. Clip-on devices are more easily dislodged and more likely to indicate lower levels of saturation when compared with devices taped onto the patient. In addition, many clip-on devices are not appropriately sized for infants and young children. As such, single-use disposable probes that tape onto the patient are recommended. Advances

in monitoring technology have also led to the development of probes that can be placed on the forehead to provide accurate determinations of oxygen saturation, even during low-flow states.<sup>13</sup> Easy to use portable devices that can be clipped onto a finger are now available (eg, Onyx, Nonin Medical Inc, Plymouth, MN) (Figure 4-1). These can be used during patient transport, especially between treatment and recovery rooms.

Another limitation of current pulse oximeter technology is inaccuracy caused by abnormal hemoglobin molecules, methemoglobin, or carboxyhemoglobin. Emerging technology in pulse oximetry includes new devices that use multiple wavelengths of light, thereby allowing measurement of various hemoglobin species including carboxyhemoglobin and methemoglobin, and the incorporation of technology that allows continuous measurement of hemoglobin (Masimo Corporation, Irvine, CA).<sup>14</sup> This technology may provide improved oximetry monitoring during movement and low perfusion states.<sup>15</sup> Further development has led to the incorporation of technology that may indirectly provide information for the continuous assessment of cardiovascular performance, including the pulse variability index as a measure of intravascular volume and the perfusion index as a measure of distal perfusion and systemic vascular resistance.<sup>16</sup> Although still in its early stages in the pediatric population, the applications of such technology may provide additional avenues of monitoring during procedural sedation.

**Figure 4-1**



This portable pulse oximetry device provides a visual readout of the pulse oximetry value without a plethysmograph, can be clipped onto a finger, and may be useful during transport. Courtesy of Nonin Medical, Inc.

## Noninvasive Blood Pressure Monitoring

Noninvasive blood pressure (NIBP) monitoring has been widely used in operating rooms and critical care units since the 1970s.<sup>7</sup> Most NIBP devices employ oscillometric technology that relies on fairly regular cardiac rhythms to determine blood pressure (BP). Irregular or rapid cardiac rhythms may make it difficult to accurately determine BP. The accuracy of NIBP monitoring is affected by movement, agitation, location of the NIBP cuff on the

patient, and cuff size. A cuff that is too small may lead to a falsely elevated BP, while a cuff that is too large will lead to a falsely low BP. Cuff width should equal 40% of the arm circumference.<sup>17</sup> American Heart Association recommendations for cuff sizes based on upper-arm circumference are listed in Table 4-1.<sup>17</sup>

When comparing NIBP with direct arterial pressures, values are typically within 5 mm Hg of each other. However, the difference can vary by as much as 30 to 40 mm Hg, and therefore a single, noninvasive measurement should not be used to redirect therapy.<sup>18,19</sup> However, indirect BP measured with automatic monitors such as the Dinamap more accurately reflect direct radial artery pressure than the auscultatory method.<sup>19</sup> The 2006 AAP guidelines for monitoring during sedation recommend intermittent BP monitoring at a minimum of every 5 minutes.<sup>19</sup> However, there are limited data as to whether NIBP monitoring prevents adverse events. In the study of 1,256 events during general anesthesia, only 12% were detected by BP monitoring, the fourth largest group when comparing different monitoring modalities.<sup>20</sup> The majority of these were detected by invasive BP monitoring.

Regular BP monitoring has become especially important in recent years due to the more frequent use of medications that induce deep sedation and the ever-increasing comorbid conditions that may affect our patients. Medications generally alter BP by affecting autonomic responses. Certain medications such as ketamine generally cause an increase in BP, while

**Table 4-1. American Heart Association Recommendations  
for Blood Pressure Cuff Size<sup>a</sup>**

Extremity Circumference (cm)	Cuff Name
5–7.5	Newborn
7.5–13	Infant
13–20	Child
17–25	Small adult
24–32	Adult
32–42	Wide/large adult
42–50	Thigh

<sup>a</sup>Size is based on upper arm circumference, which is measured at the middle of the upper arm.

Adapted from: Frohlich ED, Grim C, Labarthe DR, Maxwell MH, Perloff D, Weidman WH. Recommendations for human blood pressure determination by sphygmomanometers. Report of a special task force appointed by the steering committee, American Heart Association. *AHA News*. 1988;11:217A, by permission of American Heart Association, Inc.

medications like propofol may induce significant hypotension in up to 50% of patients.<sup>21</sup> Continuous heart rate monitoring and frequent BP measurements also provide an indication of sedation adequacy during painful procedures and are used as a guide to treatment. Monitoring BP every 5 minutes is recommended unless monitoring specifically interferes with the procedure, such that arousal of the patient with the BP cuff insufflations would interfere with a procedure such as an MRI. New technology in BP monitoring continues to develop, including devices that may be able to noninvasively provide a continuous BP measurement similar to that provided by invasive, intra-arterial monitoring. Although the applications of these devices have been limited in the pediatric population, these may see increased use in the years to come.<sup>22</sup>

## Electrocardiography and Respiratory Monitoring

Continuous heart rate and respiratory monitoring during procedural sedation are recommended by the AAP.<sup>12</sup> The typical electrocardiograph (ECG) monitors heart rate and rhythm using 3 electrodes that provide rhythm evaluations using leads I, II, and III. More involved monitoring, which may be used in patients with associated comorbid conditions, uses additional leads (up to 5), thereby allowing monitoring of chest leads (V<sub>1-6</sub>), which may be useful for detecting ischemia or improved rhythm analysis. Multiple sedation medications cause a decreased heart rate via inotropic and chronotropic reductions and increased vagal tone. Some sedation medications, such as ketamine, may result in a dose-related increase in heart rate and BP. Importantly, increased heart rate during painful procedures may suggest inadequate sedation. There are limited data on the actual value of ECG monitoring during sedation, especially given that the primary data, heart and respiratory rate, are readily captured by other monitoring modalities, including pulse oximetry and capnography. Additionally, studies during anesthesia have demonstrated that significant physiological changes can occur, such as hypotension, hypercapnia, and hypoxemia, without changes in heart rate or rhythm.<sup>23</sup>

Although ECG monitoring does provide rhythm monitoring should a pre-arrest or arrest rhythm develop, the incidence of these events is low during procedural sedation.<sup>24</sup> In a study of 17,999 consecutive sedations for endoscopy, bradycardia developed in 1.16% of cases and arrhythmias in 0.21%.<sup>25</sup> In the study of 1,256 events during general anesthesia, ECG

monitoring ranked third, after pulse oximetry and capnography and just before BP monitoring, in being the first monitor to detect an incident. However, in 98% of these cases, the ECG only detected changes in heart rate.<sup>26</sup> In the theoretic analysis of the cases, the addition of ECG to pulse oximetry and capnography increased the potential to detect events by less than 0.5%.<sup>2</sup>

When local anesthetic agents (especially bupivacaine and ropivacaine) are used during a painful procedure or regional block, ECG monitoring is essential because it provides the earliest indication of impending cardiovascular collapse. When epinephrine is added to the local anesthetic solution, inadvertent systemic injection is noted by changes in T-wave amplitude, heart rate, and BP.<sup>27</sup> Local anesthetic toxicity, though rare, can be life-threatening, and early treatment with intra-lipid has proven to be particularly efficacious.<sup>28</sup> Because neurologic symptoms are generally masked by sedation, changes in T-wave amplitude or heart rate may be the first sign of dangerously increased intravascular concentration of the local anesthetic agent.

Electrocardiograph electrodes allow respiratory rate monitoring through transthoracic impedance pneumography. Impedance is measured by passing low-amplitude, high-frequency alternating current between 2 surface electrodes. If respiration ceases secondary to central apnea, the impedance monitor should detect the cessation of respiratory effort. However, the use of thoracic impedance monitoring to detect respiration is potentially detrimental if used as the only monitor of ventilation. While the voltage across the thorax fluctuates during inspiration and expiration, allowing the measurement of respiratory rate, in reality the impedance will change with chest wall movement alone.<sup>29</sup> Impedance measurements detect respiratory effort but not ventilation. A patient experiencing obstructive apnea or laryngospasm will appear to have a normal measurement of effective respiration. Capnography, visual observation of the thorax, or continuous auscultation of respiration (precordial stethoscope) provides a much better monitor for the cessation of ventilation.

In an effort to improve monitoring safety following sedation or general anesthesia, there has been interest in the development of techniques to effectively monitor respiratory function, in particular the respiratory rate. Although this can be done with capnography, placement of nasal cannula may be bothersome to the patient. As such, the Masimo Corporation has

developed a device that noninvasively and continuously measures respiration rate using an adhesive sensor with an integrated acoustic transducer applied to the patient's neck.<sup>30</sup> Using acoustic signal processing with patented Signal Extraction Technology, the respiratory signal is separated and processed to display a continuous respiration rate. This technology has been incorporated into a perioperative monitoring platform as an adjunct to other monitoring technologies, including ECG, capnography, and pulse oximetry.

## Capnography and End-tidal Carbon Dioxide Monitoring

The most likely adverse event in children undergoing procedural sedation remains an adverse effect on respiratory function, including upper airway obstruction, hypoventilation, or apnea. Although periodic respiratory rate monitoring and pulse oximetry are mandatory during procedural sedation, these modalities are not helpful in immediately detecting airway obstruction or inadequate respiratory depth and are often slow in detecting periods of apnea. Noninvasive measurement and monitoring of expired CO<sub>2</sub> (capnography) can provide an early indication of inadequate respiratory effort and provide additional safety during sedation.<sup>31</sup> Capnography has been a standard during general anesthesia for more than 20 years and is encouraged during deep sedation by The Joint Commission, ASA, and AAP.

End-tidal carbon dioxide monitoring employs infrared technology to measure the amount of CO<sub>2</sub> in an aliquot of expired gas. In ideal circumstances, when there is no entrainment of room air, there is effective matching of ventilation and perfusion, and the aliquot of gas represents only expired CO<sub>2</sub> from the patient's lungs (eg, endotracheal intubation), the maximum reading or end-tidal point closely correlates with arterial CO<sub>2</sub>. However, sampling issues may affect this correlation. In spontaneously breathing and sedated patients who breathe from the nose and mouth, the ET-CO<sub>2</sub> reading does not necessarily provide an accurate measure of arterial CO<sub>2</sub>. Despite this, the breath-to-breath expired CO<sub>2</sub> tracings still provide important information about the presence and adequacy of ventilation as well as airway patency. With cessation of gas exchange related to apnea or upper airway obstruction, there is an immediate extinguishing of the capnograph, thereby alerting the health care practitioner to the adverse event. As noted previously, hypoxemia manifested as a decrease in pulse oximeter value may take minutes to develop. The increased availability of nasal cannulas of various sizes and

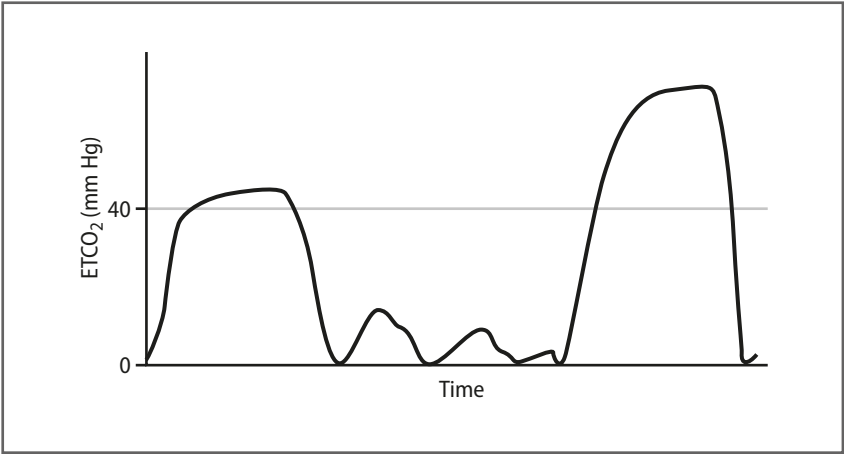
shapes to monitor expired CO<sub>2</sub> in spontaneously breathing patients has allowed this technology to expand to the emergency department, radiology suite, and other areas that perform procedural sedation.<sup>32–37</sup> These devices include the possibility of sampling exhaled gas from the mouth and nose. Availability of smaller and more portable capnograph devices has made this technology available in a number of outpatient and inpatient settings.

Because spontaneously breathing pediatric patients often have small tidal volumes and are most at risk for airway obstruction and apnea, a capnograph using micro-stream technology (Oridion Medical/Covidien, Mansfield, MA), which allows analysis of expired CO<sub>2</sub> using much smaller samples (50 mL/min), has been an important advance for capnography during procedural sedation. Nasal cannulas and nasal/oral cannulas are available that can measure expired CO<sub>2</sub> and provide supplemental oxygen. Even in the presence of supplemental oxygen, these monitors can detect periods of apnea and inadequate ventilation at the immediate onset of the event, something that may not be detected by visual inspection or respiratory rate monitoring.<sup>36,38,39</sup> A recent study in pediatric patients undergoing gastrointestinal endoscopy indicated that early detection of inadequate ventilation and prompt intervention led to fewer episodes of oxygen desaturation.<sup>40</sup> In the study of the value of various monitoring modalities among 1,256 incidents during general anesthesia, capnography ranked second after pulse oximetry for detecting significant problems. In a theoretic analysis of the same patients, the authors conclude that had capnography been used as the sole means of monitoring the patients, 55% of the incidents would have been detected.<sup>41</sup>

In addition to providing a value (ETCO<sub>2</sub>), capnography provides the capnograph or a visual depiction of CO<sub>2</sub> expiration over time, which may provide additional information about respiratory function. Procedural sedation routinely induces hypoventilation, especially when opioids or propofol is administered. When supplemental oxygen is used, mild hypoventilation is generally of less concern than apnea or upper airway obstruction. Capnography can rapidly determine these 2 complications by providing breath-to-breath CO<sub>2</sub> analysis. The trained observer can then quickly determine when ventilation appears inadequate and readjust the airway to improve ventilation (figures 4-2 to 4-4). A suggested algorithm for investigation and interventions for a flat ETCO<sub>2</sub> tracing is provided in Figure 4-5.

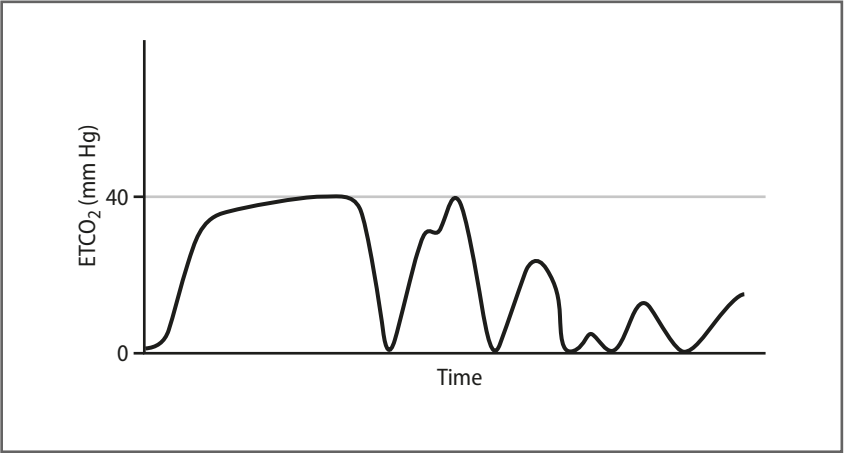


Figure 4-2

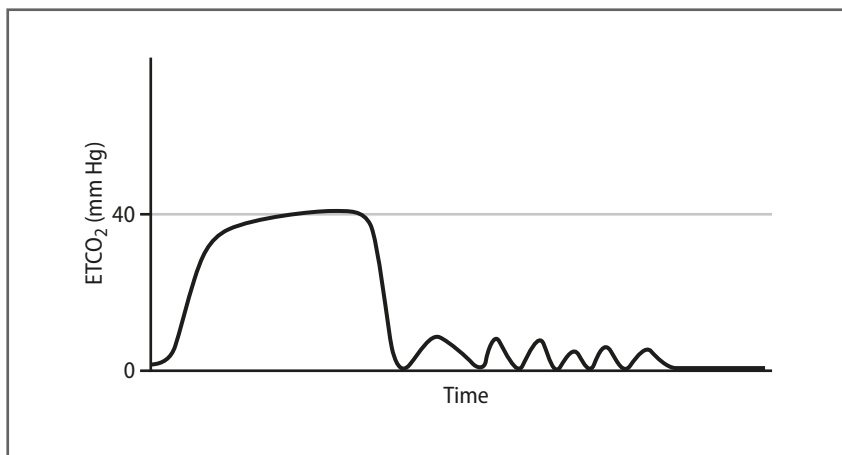


Hypoventilation with shallow respirations followed by a deep breath. The period of hypoventilation indicated above was followed by a deep breath and a more accurate reflection of alveolar CO<sub>2</sub>.

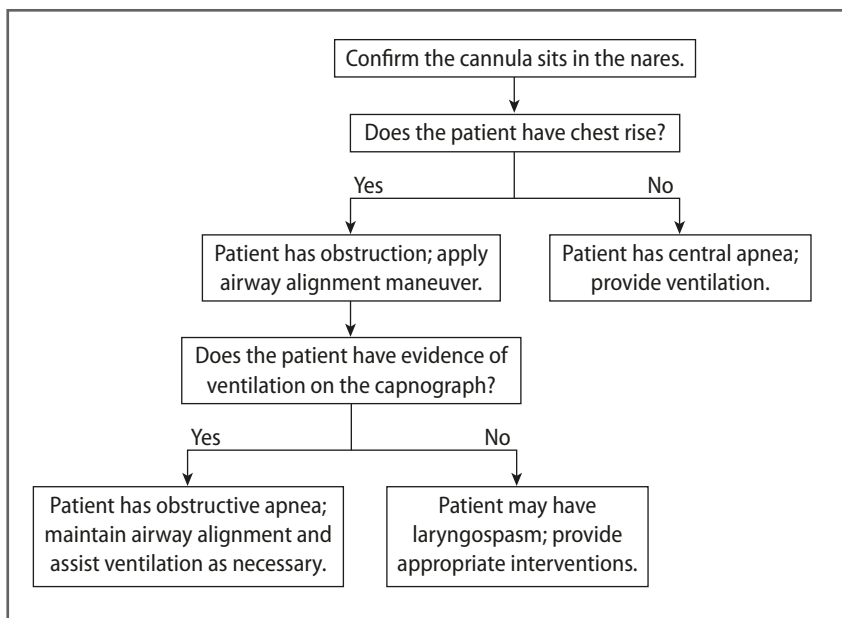
Figure 4-3



Change in alveolar plateau indicative of incomplete alveolar emptying and loss of airway integrity. This type of tracing represents partial airway obstruction and can alert the practitioner when patency of the airway needs evaluation. A readjustment of the head, jaw thrust, or chin lift may improve ventilation without further intervention.

**Figure 4-4**

Sudden loss of end-tidal CO<sub>2</sub> (ETCO<sub>2</sub>) suggestive of apnea or complete airway obstruction. This tracing suggests partial airway obstruction followed by apnea or complete airway obstruction. The algorithm in Figure 4-5 suggests a quick approach to the evaluation of the patient with a flatlined ETCO<sub>2</sub>, which will allow the practitioner to provide the appropriate interventions required to improve airway integrity or stimulate breathing in the deeply sedated patient, often prior to oxygen desaturation.

**Figure 4-5**

Evaluation of the flatlined end-tidal CO<sub>2</sub>

## Depth of Sedation Monitoring Including the Bispectral Index

Regardless of the agent and dosages used, pediatric patients can easily drift into deeper than intended levels of sedation, and these deeper levels are associated with a higher incidence of respiratory compromise.<sup>42–44</sup> Therefore, monitoring the depth of sedation using sedation scales is recommended during and after procedures that require moderate or deep sedation. These data can also be used to assess the efficacy of sedation and the need to alert sedation practitioners if an appropriate depth is not consistently achieved. During lighter planes of sedation, the depth may be assessed by the patient's ability to appropriately respond to questions or verbal stimuli. For deeper levels of sedation, a variety of sedation scales have been developed to better quantify the degree of unconsciousness, including the Observer's Assessment of Alertness/Sedation (OAAS) scale, the Vancouver Sedative Recovery Scale, and the University of Michigan Sedation Scale (UMSS).<sup>45–47</sup> Although validated in children and adults, each of these scales may have specific drawbacks during procedural sedation. The OAAS, although effective in differentiating light from deep sedation, may be less effective in differentiating deeper levels of sedation from each other. The Vancouver Sedative Recovery Scale, although better at differentiating deeper levels of sedation, is too cumbersome to easily use during short procedures. The UMSS was developed as a simple and efficient tool to assess the depth of sedation over the entire sedation continuum. It uses a simple scale ranging from 0 to 4 (0 being an awake, alert patient and 4 indicating unresponsiveness). However, like the other scales, it requires patient stimulation to make an assessment. As such, these clinical sedation scales may not be acceptable for many procedures because the goal is to have the patient immobile.

Because many sedation scales require the application of a verbal or painful stimulus to elicit a response and thereby judge the depth of sedation, BIS monitoring holds particular appeal for procedures in which deep sedation is expected and the stimulation required to elicit a sedation measurement may interfere with the procedure (eg, imaging in the radiology suite). The BIS monitor was approved for use as a measure of depth of anesthesia in 1991. It uses a processed electroencephalogram (EEG) reading obtained from a monitor on the forehead (Figure 4-6) to calculate a number between 0 and 100 that corresponds to sedation depth. The higher the BIS score, the more alert the patient. Ranges have been determined by the manufacturer (Aspect

Medical/Covidien, Mansfield, MA) to indicate levels of sedation: 40 to 60 indicates general anesthesia; 61 to 70, deep sedation; 71 to 90, moderate sedation; and greater than 90, the awake state. This number appears to correlate well with the depth of anesthesia when using inhalation anesthetic agents and with intravenous anesthetic or sedative agents that work through the gamma-amino butyric acid system, such as propofol, benzodiazepines, and barbiturates, but does not correlate as well with other agents, including ketamine, chloral hydrate, and perhaps dexmedetomidine.<sup>48,49</sup> In general, sedation regimens using a combination of midazolam and fentanyl or propofol show a closer correlation between BIS and established sedation monitoring scales such as the Ramsay Scale or the UMSS.<sup>42,44,48,50,51</sup>

**Figure 4-6**



The bispectral index (BIS) monitor was approved for use as a measure of depth of anesthesia in 1991. It uses a processed electroencephalogram reading obtained from a monitor on the forehead to calculate a number between 0 and 100 that corresponds to sedation depth. Courtesy of Joseph D. Tobias, MD, FAAP.

Gill et al compared BIS values with Ramsay sedation scores in 37 adult patients receiving procedural sedation or analgesia in the emergency department setting.<sup>52</sup> Although there was a significant correlation between BIS and depth of sedation, the authors reported a wide variability in BIS values at similar sedation scores. The BIS was most effective in differentiating moderate to deep sedation from general anesthesia, which is arguably one of the more important distinctions being sought, given the studies demonstrating an increased incidence of adverse events as the depth of sedation progresses. The potential to limit adverse effects by using depth of anesthesia/sedation monitoring is illustrated by a prospective study of 86 children undergoing procedural sedation.<sup>42</sup> Adverse respiratory and airway events were more common in patients with BIS values indicative of deep sedation (61–70) or general anesthesia. Oxygen desaturation occurred in 6 of 41 patients in the deep sedation or general anesthesia group, compared with 1 of 28 in the awake (BIS >90) or moderate sedation (BIS 71–90) group. Airway issues occurred in 7 of 41 patients in the deep sedation or general anesthesia group, compared with 0 of 28 in the awake or moderate sedation group. In other

studies, the BIS monitor has been used to titrate depth of sedation using propofol as well as a means of assessing discharge readiness.<sup>44,50</sup> Despite this work, caution in interpretation of these data is advised, as the BIS algorithm was developed in adult patients and is therefore based on the adult EEG pattern. Additionally, it was developed when sedation/anesthesia was provided by volatile anesthetic agents or propofol so extrapolation to other agents may be problematic.

Although the BIS monitor has seen the greatest use, there are other monitors that may be useful in the arena of procedural sedation. One of the newer sedation depth technologies that has been introduced into the operating room setting is entropy-based monitoring. Variability and irregularity in the processed EEG and electromyography (EMG) signals from the forehead are used to gauge depth of sedation based on the central nervous system response to anesthetic agents. When compared with the BIS monitor, entropy is different in that it uses not only the processed EEG but also EMG. This may allow not only an assessment of the depth of sedation but also a measure of pain or the nociceptive input to the patient by measuring changes in the EMG from the frontalis muscle. In the normal, non-sedated state, there are high levels of entropy activity with considerable variability in EEG and EMG signals. With an increasing depth of sedation, EEG cortical electrical activity becomes more regular with decreased variability. Likewise, the EMG of the forehead muscle activity decreases and ultimately ceases (low levels of entropy activity). To date, this technology has not been studied outside of the operating room, but it may prove to be a valuable adjunct during procedural sedation.<sup>53</sup>

## Summary

Appropriate monitoring of patients during procedural sedation plays a key role in ensuring safety and the evaluation of response to therapy. Monitoring devices used in combination are key to enhancing the safety of procedural sedation. No single monitor can be expected to detect all adverse events in time for appropriate interventions. The most essential component remains a skilled health care practitioner whose only responsibility is to monitor the patient. This practitioner should have a thorough understanding of the

monitoring technology used and its limitations. While traditional monitoring of ECG, BP, and pulse oximetry has been routine for more than 20 years, capnography has become an integral part of monitoring and is rapidly being considered a standard monitoring modality during procedural sedation. We would suggest its use during any procedural sedation event. Depth of anesthesia/sedation monitoring shows tremendous promise in improving the safety of procedural sedation and as a guide to adequacy of sedation and recovery. Despite such recommendations, there has not been universal acceptance of monitoring during procedural sedation, as illustrated by surveys and reviews.<sup>54</sup> This remains problematic because there is ample information to demonstrate that inadequate monitoring remains a precipitating factor for morbidity and even mortality during procedural sedation.

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## CHAPTER 5

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# Medications Part 1: Sedatives and Anxiolytics

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## Introduction



Once it has been established that a patient requires and is a candidate for procedural sedation, an appropriate agent or regimen must be chosen. The ideal sedative regimen would display a number of desirable characteristics, including a rapid onset of action, predictable duration, easy titration, rapid cessation of effects once discontinued, multiple delivery options, wide therapeutic window, minimal cardiopulmonary effects or interactions, minimal drug interactions, and minimal effects from renal or hepatic disease. Unfortunately, such an agent does not exist and, even if it did, might not be routinely applicable to all scenarios the sedation practitioner may face. Thus, decisions about which agents are to be used will be influenced by a variety of factors, including the procedure being performed, depth of sedation required, need for or presence of intravenous (IV) access, the patient's previous experiences with sedation or anesthesia, and risk factors or comorbid conditions identified in the pre-sedation assessment. Of particular importance is the type of procedure (eg, painful versus non-painful, invasive versus noninvasive), as properties such as sedation, anxiolysis, and analgesia differ between agents. This chapter will discuss these factors in more detail as well as initiate discussion of the agents available, focusing on those with only sedative or anxiolytic properties. Agents with more potent analgesic properties will be discussed in Chapter 6.

## Choice of Agent

As the number of procedures for which sedation is provided continues to expand, it is logical that the procedure itself will most significantly dictate the choice of agent(s) used. Three procedure characteristics most significantly influence drug choice: degree of associated pain, discomfort, or invasiveness; degree of immobility required; and duration. Painful or invasive procedures (eg, lumbar puncture, fracture reduction, endoscopic evaluations) require agent(s) with sedating and analgesic properties, while for noninvasive procedures (eg, nuclear medicine, magnetic resonance imaging [MRI], neurophysiologic studies), sedation alone is usually sufficient. Alternatively, pure sedative agents can be used for painful procedures with the liberal and effective use of topical and subcutaneous local anesthetic agents (see Chapter 10 for a full discussion of the use of local anesthetic agents). As such, for a painful procedure, 2 agents may be combined using the sedative properties of one and the analgesic properties of another. A related but separate consideration is the degree of immobility required; this is equally relevant to painful and non-painful procedures. For example, more movement can be tolerated during a fracture reduction than a lumbar puncture or during electroencephalography than MRI. In general, as the tolerance for mobility decreases, a deeper depth of sedation will be required. In many instances, this factor eliminates certain agents from consideration, as production of adequately deep sedation to ensure immobility may not be possible without an intolerable risk of adverse effects. While procedure duration is not always predictable, ideally one would use shorter-acting agents for procedures expected to be brief, such as lumbar puncture or computed tomography (CT), and longer-acting agents or short-acting agents as infusions for lengthier procedures (eg, MRI, nuclear medicine).

Route of delivery of the sedative drug is also important, particularly in children who may not require IV access for the procedure itself. In these situations, non-parenteral administration options (eg, oral, rectal, buccal, intranasal) may be most appropriate, as the experience of starting an IV cannula or an intramuscular (IM) injection may be viewed as being more distressful than the procedure itself. However, this outcome needs to be balanced against the risk of adverse events from the sedative agent(s), which may require IV access to allow resuscitative interventions. Furthermore, the associated increase in variability of onset and recovery times and the

uncertainty of sedation depth achieved with the non-parenteral administration of these agents may significantly affect success of the procedure and sedation unit flow. Consequently, the inconvenience and pain of placing an IV cannula may outweigh other considerations. Wider availability of topical anesthetic agents to facilitate IV starts makes presentation of this option to a family and patient an important component of the sedation plan discussion. Alternatively, the IV cannula may be placed following the achievement of anxiolysis and, many times, amnesia with an oral agent or administration of nitrous oxide (see Chapter 6). See Table 5-1 for a summary of procedural sedation agents, doses, and properties.

## Specific Agents

### Barbiturates

Barbiturates have a long history in the practice of medicine, having been introduced into clinical practice in 1934. The ring of the chemical structure of barbiturates can contain a sulfur atom (thiobarbiturates, eg, thiamylal, thiopental) or an oxygen atom (methohexital). A sulfur atom instead of an oxygen atom in the ring results in a more rapid onset and shorter duration of action. Increasing the length of the carbon side chains at position 5 of the ring increases the compound potency. Short-acting agents such as methohexital, thiopental, and thiamylal have a clinical duration of action of 5 to 10 minutes and are used most commonly as a single bolus dose for the induction of anesthesia. When a more prolonged effect is needed, a continuous infusion may be used to maintain constant plasma levels. Alternatively, the duration of action of short-acting agents may be prolonged when they are administered by non-parenteral routes, such as per-rectum administration of methohexital for radiologic imaging. Long-acting agents with half-lives of 6 to 12 hours include pentobarbital and phenobarbital. Clinical effects of short-acting agents dissipate rapidly following IV administration because of redistribution, as their hepatic metabolism may take hours. Given their short duration of effect following a single bolus dose, if a more prolonged effect is required, short-acting agents may be administered by continuous infusion. When delivered in this manner, offset time will also be markedly prolonged and dependent on the duration of infusion.

**Table 5-1. Summary of Procedural Sedation Agents, Doses, and Properties**

Agent	Route	Dose	Onset	Duration	Applications/Comments
Barbiturates					
Pentobarbital	IV	1–2 mg/kg initial 0.5–1 mg/kg subsequent (maximum 6 mg/kg total)	10–15 min	60–90 min	Noninvasive radiologic procedures
	PO	4–5 mg/kg initial 2–2.5 mg/kg subsequent	30–60 min	60–90 min	
Methohexital	IV	1 mg/kg initial 0.5–1 mg/kg subsequent	2–5 min	10–20 min	Short noninvasive procedure (CT scan)
	PR	20–30 mg/kg initial 15–20 mg/kg subsequent	10 min	30–40 min	
Benzodiazepines					
Midazolam	IV	0.02–0.05 mg/kg (maximum 2 mg per dose) Repeat dose as needed.	2–5 min	30–45 min	Anxiolysis for noninvasive radiologic imaging. Add analgesic for painful procedures. Adjunct for deeper sedating regimens.
	PO	0.5–0.7 mg/kg	5–20 min	Up to 60 min	
	IN	0.2–0.4 mg/kg	5–10 min	30–45 min	
Lorazepam	IV	0.05–0.1 mg/kg (maximum 2 mg per dose)	2–5 min	Up to 60 min	Anxiolysis for noninvasive radiologic imaging. Add analgesic for painful procedures. Adjunct for deeper sedating regimens.

**Table 5-1. Summary of Procedural Sedation Agents, Doses, and Properties, continued**

Agent	Route	Dose	Onset	Duration	Applications/Comments
<b>Others</b>					
Chloral hydrate	PO/PR	70–100 mg/kg initial Repeat 50% of initial dose (maximum 100 mg/kg or 2 g).	30–60 min	60–120+ min	Noninvasive radiologic imaging, BAER, or EEG Reliability decreased in ASD, age >48 mo
Dexmedetomidine	IV	Induction: 1–3 µg/kg Infusion: 0.5–2 µg/kg/h	10–15 min	30–45 min	Noninvasive radiologic imaging. BAER or EEG. Combine with ketamine for painful procedures.
	Oral-buccal IN	3–4 µg/kg 2–4 µg/kg	45–60 min 45 min	60–90 min 60–90 min	
Etomidate	IV	0.2 mg/kg initial 0.1 mg/kg subsequent	5 min	20–25 min	Short noninvasive procedures. Add analgesic for painful procedures. Myoclonus on induction, adrenal suppression.
Propofol	IV	1–2 mg/kg every 2–3 min Infusion 120–300 µg/kg/h	2–3 min	10–15 min	Noninvasive radiologic imaging. Add analgesic for painful procedures.

Abbreviations: ASD, autism spectrum disorder; BAER, brain stem auditory evoked response; CT, computed tomography; EEG, electroencephalogram; IN, intranasal; IV, intravenous; PO, oral; PR, per rectum.

Barbiturates have been a commonly used class of sedative agents for procedural sedation for decades. They remain in common use for sedation during non-painful procedures, most commonly radiologic imaging. Barbiturates are potent sedative agents but have no analgesic properties. They produce their effects via  $\gamma$ -aminobutyric acid (GABA)<sub>A</sub> receptor agonism, which results in hyperpolarization and subsequent inhibition of postsynaptic neuronal conduction of chloride. Sleep is induced via this inhibition in the reticular activating system. While several barbiturate agents are available for clinical use, sodium pentobarbital and methohexital remain the most commonly used today. Sodium thiopental, formerly the agent of choice for induction of anesthesia when administered intravenously, is no longer available for clinical use in the United States. Sodium pentobarbital and sodium methohexital may be administered intravenously or via enteral routes. Methohexital has also been administered rectally for procedural sedation. Both agents have the potential to cause potent respiratory depression or loss of upper airway patency. Therefore, as with all agents discussed herein, appropriate pre-sedation evaluation and intra-sedation and post-sedation monitoring, including end-tidal capnography and ready access to resuscitative and airway management, is mandatory.

### *Sodium Pentobarbital (Nembutal)*

Sodium pentobarbital is a medium-duration barbiturate and probably remains the most widely used barbiturate for procedural sedation, especially for lengthier radiologic procedures such as MRI or nuclear medicine studies. An attractive option is that it can be administered via several routes (ie, IV, oral, IM), although the IM route is rarely used any longer. Following IV administration, onset of action begins within 2 to 3 minutes, although peak sedating effects may take 5 to 10 minutes to achieve. While the elimination half-life is long (up to 20 hours) following a single IV dose, clinical duration of action is significantly shorter.

Sedation with IV pentobarbital is typically initiated with doses of 1 to 2 mg/kg every 3 to 5 minutes until sleep is induced, with a maximum recommended total dose of 5 to 6 mg/kg. Using these protocols, induction doses average 3.5 to 5 mg/kg.<sup>1-4</sup> Sedation success rates are generally high (>99%), although failure rates of up to 9% have been reported.<sup>4</sup> While the average duration of sleep is 60 to 90 minutes, a reliable duration of moderate to deep sedation is 45 to 60 minutes, which is adequate to perform most routine MRI

evaluations. If needed, repeated dosing with 1 to 2 mg/kg increments can be performed and titrated to effect.

Following oral administration, pentobarbital has excellent bioavailability (>95%). Peak absorption of capsule-based formulations occurs in 45 to 60 minutes, with some of the delay being due to initial capsule breakdown.<sup>5</sup> Oral pentobarbital is most commonly administered using the IV formulation alone or compounded into a syrup to increase palatability. This eliminates the time for capsule breakdown in the gastrointestinal (GI) tract and should improve the rate of absorption and onset of clinical effects. Its use has been almost exclusively reported in the infant and toddler population for radiologic procedures or echocardiography, with reported superiority over chloral hydrate.<sup>2,6,7</sup> Dosing regimens start with 4 to 5 mg/kg. Repeat doses of 2 to 2.5 mg/kg may be administered at 30-minute intervals to a maximum 8 mg/kg. Sedation onset ranges from 20 to 30 minutes but may take up to 60 minutes. Typical duration of sedation is 60 to 90 minutes. Sedation success rates are 95% to 99%, and most patients successfully sedate with a single dose. Warden et al found that toddlers were more likely than infants to require repeat doses.<sup>7</sup> While overall sedation duration (time from administration to discharge) is longer than with IV pentobarbital, adverse events are less common, with reported respiratory and behavior-related event rates of less than 1% each.<sup>2,6,7</sup>

The most commonly reported side effects are respiratory and behavioral. While apnea may be observed, it is rare and occurs most commonly in infants or following rapid administration. The most commonly observed respiratory effects are minor and include mild hypoxemia or upper airway obstruction. There are insufficient data reported to assess rates of hypoventilation. Paradoxical or recovery-related agitation can also be a significant issue and may occur in up to 10% of patients. While limited, available data do not support perceptions that midazolam pretreatment ameliorates this behavior.<sup>8</sup> Treatment can be provided by caffeine, most commonly administered via the oral route using a caffeinated beverage such as Mountain Dew (1.0–2.5 mg/kg caffeine).<sup>9</sup> Intravenous administration of caffeine has also been reported in doses of 20 mg/kg to a maximum of 200 mg.<sup>9</sup> When comparing IV pentobarbital to IV dexmedetomidine, although the average time to achieve sedation was longer with dexmedetomidine ( $12 \pm 4$  versus  $6 \pm 3$  minutes,  $P < 0.001$ ), recovery time was more rapid with dexmedetomidine



( $32 \pm 18$  versus  $95 \pm 28$  minutes,  $P < 0.001$ ), and the incidence of emergence agitation was significantly less.<sup>10</sup>

### *Methohexital (Brevital)*

Methohexital is a short-acting oxy-barbiturate with a lengthy history of use in radiology and dental sedation. Although initial reports focused on its rectal administration, there has been increasing interest in IV administration for painful and non-painful procedures.<sup>11–15</sup> The latter has been prompted in part by the inability to obtain thiopental in the United States. Due to its short duration of action with rapid redistribution following IV administration, methohexital has been used primarily for short-duration procedures.

Typical induction IV dosing is 1 mg/kg, which may be supplemented with 0.5 to 1 mg/kg doses titrated to effect. Due to rapid central nervous system (CNS) penetration (<1 minute), supplemental doses may be given as soon as 2 to 4 minutes following initial induction. Clinical onset of action is rapid (1–2 minutes), and average duration of sedation is 10 to 20 minutes, with complete recovery usually being observed by 40 to 50 minutes following administration. Dosing does not appear to be different when used for painless versus painful procedures, regardless of whether additional analgesic agents were used.<sup>13–15</sup> However, there may be a significant variation in the total dose required for the procedure, with one study reporting an average dose of 4.6 mg/kg with a range of 1 to 9 mg/kg.<sup>13</sup> In most series, the incidence of sedation failures is low (<1%). Austin et al reported a success rate of only 79% following methohexital sedation for primarily joint reduction procedures in the emergency department.<sup>15</sup> However, it was not specified if these failures were the result of sedation-related or procedure-related issues. The adverse effect profile of methohexital differs somewhat from IV pentobarbital sedation, with a higher observed incidence of respiratory events (eg, hypoxemia, airway obstruction) and less recovery-related agitation.

Due to its limited bioavailability of 17%, rectal dosing of methohexital is significantly higher than IV use at 20 to 30 mg/kg.<sup>16</sup> Absorption is rapid, with onset of sleep occurring in 8 to 10 minutes. If sedation is inadequate, repeat dosing (50%–75% of the initial dose) may be given as soon as 15 minutes after the initial dose. Mean duration of sedation is 30 to 40 minutes, and most patients return to baseline by 90 to 120 minutes after dosing. Significant adverse events, primarily mild respiratory depression or hypoxemia, are not uncommon (up to 10%) but are more frequent than with oral pentobarbital.

Sedation failures are also more frequent than with oral pentobarbital, occurring in 5% to 13% of recipients.<sup>11,12</sup> While barbiturates are more widely known for their anticonvulsant properties, methohexital has been reported to have excitatory effects and may precipitate seizures in patients with underlying seizure disorders.<sup>17</sup> An additional consideration is prolonged awakening, which may be particularly bothersome following brief procedures.

## Benzodiazepines

As a drug class, benzodiazepines are anxiolytic and sedative-hypnotic agents. They produce antegrade and retrograde amnesia, muscle relaxation, and sedation but have no analgesic properties. Sedation is induced via GABA<sub>A</sub> receptor-mediated potentiation of the inhibition of chloride currents. As a sole agent, benzodiazepines are used most commonly to produce anxiolysis or mild to moderate sedation. When used in deeply sedating doses, risks of significant respiratory depression are substantial. Unlike other sedative classes, benzodiazepines are usually coadministered with other agents as a premedication prelude to the use of a more deeply sedating regimen or as a sedative adjunct to more potent analgesics (ie, opioids, ketamine) for painful procedures. Due to several pharmacologic properties, midazolam is the benzodiazepine of choice for most procedure-related applications. It is water soluble, so there is no pain with IV administration, multiple effective delivery routes are available, and it has a relatively short elimination half-life. In comparison, lorazepam has a long duration of action relative to the length of most procedures.

### *Midazolam (Versed)*

A significant advantage of midazolam is that it can be effectively used via multiple routes of administration. Its availability in generic forms limits cost. Choice of route will depend on desired depth of sedation, patient cooperation given its palatability, and presence of IV access. If vascular access is present, IV administration is preferred. Standard IV dosing starts with increments of 0.02 to 0.05 mg/kg initially, with repeat dosing titrated to effect. Depending on duration of the procedure, higher cumulative doses (0.3–0.5 mg/kg) may be required, depending on the use of adjunct medications and the patient's comorbid conditions. Anxiolysis or sedation typically occurs within 3 to 5 minutes of IV administration. Duration of effective

sedation is 30 to 45 minutes. The latter may be affected by coadministration of other agents.

Intravenous midazolam is most commonly used as an adjunct sedative with opioids or ketamine for painful procedures.<sup>18–20</sup> When combined with opioids, it is usually to add sedation and amnesia to the primary analgesia provided by opioids, whereas, when added to ketamine sedation, the intent is primarily to offset unpleasant adverse effects of ketamine, especially nausea and emergence reactions, although literature supporting these benefits is inconsistent.<sup>21–23</sup> There is also evidence that adjunct midazolam blunts but does not abolish ketamine-associated increases in intracranial pressure, which may be of clinical significance when using ketamine-midazolam regimens for lumbar puncture and measurement of opening pressure.<sup>24</sup>

For minor procedures with which IV access is neither required nor desired, non-parenteral routes may be used. Initial applications used oral midazolam, in doses ranging from 0.5 to 0.7 mg/kg.<sup>25,26</sup> Anxiolysis occurs in 15 to 20 minutes and lasts for an average of 60 minutes. While moderate to deeper sedation may occur with oral midazolam, it is uncommon, and oral midazolam alone should only be relied on for situations requiring mild sedation or anxiolysis in which some degree of movement can be tolerated. While data are limited, significant respiratory depression appears uncommon when midazolam is used alone, although risk increases when it is coadministered with other agents.<sup>25</sup>

Initial clinical trials with oral midazolam used the IV formulation and administered it orally. The disadvantages of this practice include not only the taste related to the preservative, benzyl alcohol, but also alterations in the drug's bioavailability, thereby requiring doses in excess of 0.5 mg/kg.<sup>27</sup> Although the taste of the IV solution may be masked by mixing the drug in some type of flavored solution, a commercially available preparation of midazolam in a cherry-flavored solution for oral administration is also available and generally preferred. One disadvantage of this oral solution is that it is less concentrated (2 mg/mL), so a larger volume is needed. Clinical data suggest that effective sedation can be achieved with doses as low as 0.25 mg/kg compared with 0.5 to 1.0 mg/kg doses reported when using the IV preparation diluted in other solutions for oral administration.<sup>27</sup>

An alternative non-enteral route for midazolam administration is intranasal. Midazolam is rapidly absorbed across nasal mucosal surfaces, with sedation occurring in as little as 5 to 10 minutes. Increased bioavailability also mandates a dose reduction (0.2–0.4 mg/kg) compared with oral administration.<sup>28,29</sup> For nasal administration, use of the more concentrated 5-mg/mL IV preparation is suggested because it results in a lower volume that must be administered. Use of an atomizer (Mucosal Atomization Device [MAD], Wolfe Troy Medical, Salt Lake City, UT) to better disperse the drug compared with drop administration may result in more consistent effects, although efficacy appears similar with both methods. Nasal discomfort experienced during administration of midazolam alone may be ameliorated with lidocaine coadministration.<sup>30</sup> As with oral use, the sedation achieved with intranasal midazolam is typically mild to moderate, and while this will not generally be sufficient for more painful procedures, intranasal midazolam as a sole agent may provide effective sedation for a variety of simple dental and emergency department procedures in well-screened populations.<sup>29,31</sup> In addition to pain with administration, the other concern with nasal administration is patient factors that may alter absorption, including an ongoing upper respiratory tract infection with nasal congestion or the concomitant administration of other nasal medications such as nasal steroid preparations.

These non-parenteral routes of midazolam administration may be combined with application of a topical anesthetic cream to provide anxiolysis during placement of an IV cannula, which can then be used for the administration of agents to achieve a deeper level of sedation. Apart from that, oral or intranasal midazolam is often also sufficient for the anxious child undergoing a noninvasive radiologic procedure. Consistent with the lighter level of sedation, significant respiratory depression is rare.

Regardless of administration route, midazolam has a relatively wide safety margin. When used as a sole agent, adverse cardiorespiratory events (eg, hypoxemia, airway obstruction, hypotension) are uncommon and typically minor.<sup>23,28–31</sup> However, when administered with other agents, particularly opioids, or in patients with significant comorbid diseases, significant respiratory or cardiovascular depression may develop. Paradoxical excitement or delirium can occur, usually following IV use and if there is associated pain. If these are significant, the administration of flumazenil may be considered.<sup>32</sup>

### *Lorazepam (Ativan)*

Lorazepam appears to be used much less frequently than midazolam as a primary procedural sedation agent. While its onset of action is similar to midazolam when administered intravenously, it has a longer duration of action ( $\geq 60$  minutes). As most procedures requiring sedation are shorter than this, there remains a preference among clinicians for midazolam in this arena. Dosing is similar to midazolam at 0.03 to 0.05 mg/kg IV. Limited data exist describing coadministration of lorazepam with other agents, particularly analgesics, for painful procedures. Its use in procedural sedation appears primarily limited to anxiolysis in older children for noninvasive studies with little motion tolerance, such as MRI. The potential for adverse effects is similar to that described for midazolam. Because use in this setting is for a limited period, propylene glycol accumulation and intoxication are not a concern.

### *Benzodiazepine Antagonists*

Flumazenil (Romazicon) is the only benzodiazepine antagonist currently available for clinical use. It competitively binds to central benzodiazepine receptors, thereby displacing benzodiazepine and inhibiting GABA receptor activation.<sup>33</sup> Whereas opioid antagonists tend to reverse sedation and respiratory depression, flumazenil primarily reverses sedation with less effect on respiratory depression. As a very lipophilic agent, its onset of action is rapid (1–2 minutes), but its duration of action is also short (30–45 minutes) and re-sedation is a real risk.<sup>34</sup> The recommended dose is 0.01 to 0.02 mg/kg, administered every 1 to 2 minutes to a maximum of 1 mg. Larger doses increase the risk of precipitating an acute withdrawal reaction, including seizures. In situations in which the perceived risk of re-sedation after single dosing is high, an infusion of 0.005 to 0.01 mg/kg/h may be initiated. Adverse effects occur in approximately 5% of patients, the most common being agitation, crying, aggression, headache, nausea, and dizziness. Most importantly, its administration is recommended only for the reversal of effects following acute administration of benzodiazepines. In most cases, the patient's breathing can be briefly assisted with bag-valve-mask ventilation until the effects of the benzodiazepines dissipate, thereby eliminating the need for a reversal agent. Ventilation issues are generally brief following the bolus administration of a benzodiazepine. These effects dissipate rapidly as the drug redistributes and the plasma concentration falls.

Flumazenil is contraindicated in patients receiving chronic benzodiazepine therapy because the risk of precipitating acute withdrawal reactions or seizures is significant. Coadministration with other drugs known to decrease the seizure threshold may also result in seizures. Its use has been reported to precipitate ventricular dysrhythmias when administered concomitantly with cocaine, methylxanthines, monoamine oxidase inhibitors, chloral hydrate, or tricyclic antidepressants. Despite the potential benefits of flumazenil in reversing the sedative or respiratory depressing effects of benzodiazepines, its availability does not alter the immediate bedside need for prompt detection of hypoventilation and the ability to intervene by establishing an airway and assisting ventilation.

## Chloral Hydrate

Chloral hydrate is an alcohol-based, sedative-hypnotic agent with a long history of use in procedural sedation. While it is no longer being manufactured as a suspension in the United States, this long history and its availability elsewhere mandate its continued inclusion in sedative discussions. Although still in its preliminary stages, the powdered formulation can be used to prepare an effective alternative solution for oral administration

Due to extensive clinical experience, ease of administration, and safety profile, chloral hydrate remains a popular agent for procedural sedation, especially in the neonate and younger child. While reported doses range from 30 to 100 mg/kg (maximum 2 g), the likelihood of sedation failure is high with doses of less than 60 to 70 mg/kg.<sup>35</sup> More recently, adjustment of the dose (40 mg/kg for infants and 60 mg/kg for children  $\geq 1$  year of age) has been suggested for patients who are judged to be quiet or sleepy on arrival to the sedation suite.<sup>36</sup> Administration may be oral or rectal, although efficacy and onset of action appear to be more rapid and predictable with oral administration. Chloral hydrate has purely sedative properties. As such, the most common applications have been, and remain, sedation for noninvasive procedures, including radiologic procedures, echocardiography, brain stem auditory evoked potential testing, and infant pulmonary function testing.<sup>37</sup> It may be more effective for sedation during radiologic imaging than intranasal midazolam.<sup>38</sup>

Chloral hydrate is rapidly absorbed from the GI tract and metabolized to the active compound, trichloroethanol, which is subsequently metabolized in the liver to inactive compounds. The mean time to onset of sleep is

approximately 25 minutes, although a wide range (5 to more than 120 minutes) has been reported.<sup>5,35,39</sup> Similarly, the mean duration of sleep is 60 to 90 minutes but may last as long as several hours. The latter emphasizes the need for ongoing post-sedation monitoring until the patient has returned to his or her pre-sedation level of neurologic function. While it has been generally believed that chloral hydrate produces only moderate sedation compared with other agents, Malviya et al reported deep sedation in a significant percentage of patients following chloral hydrate in doses of 50 to 75 mg/kg.<sup>40</sup> Additionally, some of the large reports, both prospective and retrospective, report apnea in a small percentage of patients, further emphasizing the need for appropriate preparation and monitoring.<sup>37,40</sup>

Other than ease of administration, a commonly quoted advantage of chloral hydrate is its favorable cardiorespiratory profile. Although most reports confirm minimal cardiorespiratory compromise, significant hypoxemia from airway obstruction or apnea during sleep, and death from respiratory depression have been reported.<sup>37,41,42</sup> There is no pharmacologic reversal agent for its physiological effects. Because of the long half-life of chloral hydrate, children should also be monitored following the procedure until fully awake, as significant post-discharge morbidity and mortality have been reported following early discharge after chloral hydrate use. Despite these concerns, chloral hydrate remains an effective agent in various clinical scenarios where sedation is required for noninvasive procedures. It remains a popular agent for sedation during echocardiography even in children with cyanotic congenital heart disease, where its safety and efficacy have been demonstrated.<sup>43</sup>

Other, more common adverse events include GI upset or vomiting (6%–7%), ataxia (17%), paradoxical agitation (2%–18%), and sedation failure (5%–10%).<sup>36,39</sup> Anecdotally, sedation failures have been found to be associated with older age (>48 months) or the presence of an underlying neurologic, especially neurobehavioral, diagnosis. Alternative agents or regimens should be considered in these populations. It has also been proposed that sedation failures are more common in fasted patients.<sup>44</sup> While this may be the case, given the potential risks related to vomiting and aspiration, whenever feasible, adherence to nil per os guidelines is recommended. Also of note is the concern about interaction of chloral hydrate with the chemotherapeutic agent, methotrexate, with a prolongation of its elimination half-life.<sup>45</sup>

## Dexmedetomidine

Dexmedetomidine represents the most recent arrival to the armamentarium of sedation practitioners. While  $\alpha$ -adrenergic agonists have been in clinical use for some time (eg, clonidine), the addition of dexmedetomidine in particular has had a significant effect on procedural sedation practices. Compared with its oral precursor, clonidine, dexmedetomidine is substantially more specific for the  $\alpha_2$ -adrenergic receptor (1,620:1 versus 200:1) and, consequently, confers the advantages of fewer cardiovascular effects at equally sedating doses.

Dexmedetomidine is a centrally acting  $\alpha_2$ -adrenergic receptor agonist. While its primary property is sedation, mediated via inhibition of the locus caeruleus, it also has some analgesic effects mediated at the spinal cord level via inhibition of the release of substance P. While these analgesic properties have been shown to decrease postoperative opioid requirements, they are insufficient to allow sole use of dexmedetomidine during painful procedures. Given these properties, it has rapidly become a favored agent in various clinical scenarios in the pediatric patient.<sup>46</sup>

The sedation induced by dexmedetomidine is somewhat unique in that it more closely resembles natural sleep than any other agent. Electroencephalograms (EEGs) obtained during dexmedetomidine sedation demonstrate an EEG pattern very similar to that observed during natural stage 2 to 3 sleep with significantly less artifact than that seen during sedation with other agents.<sup>47,48</sup> Unlike many other sedatives, dexmedetomidine also does not appear to suppress epileptiform activity, making it an attractive option for sedation during EEG evaluation for seizures.<sup>47,49</sup>

Although only manufactured as an IV formulation, dexmedetomidine has been administered via multiple alternative routes, including IM, buccal, and intranasal. It is absorbed effectively and relatively rapidly following IM injection, with peak plasma levels occurring 12 to 15 minutes following injection. Two recent reports describe IM dexmedetomidine use for radiology sedation and EEG monitoring.<sup>50,51</sup> Administered doses, which ranged from 1 to 4  $\mu\text{g}/\text{kg}$  (mean dose of 2.4 and 2.9  $\mu\text{g}/\text{kg}$  for CT and MRI, respectively) produced adequate sedation to complete all procedures. Significant adverse events did not occur, with mild hypotension (blood pressure <20% of the age-predicted normal value) not requiring intervention being the only



reported event. To limit the volume administered, if IM administration is chosen, the undiluted IV preparation (100 µg/mL) should be used.

Preliminary data suggest that, although used most commonly as a premedication in the operating room setting, the oral and buccal route may also be used for procedural sedation. Given limited data, dosing ranges have varied significantly for these routes of administration. Doses have ranged from 1 to 4 µg/kg, although reliable anxiolysis or sedation has generally required doses greater than 2.5 to 3 µg/kg.<sup>52,53</sup> Onset of sedation is slower than with IM administration, and practitioners should ideally wait at least 45 minutes after administration before further instrumentation or manipulation (eg, IV insertion) is attempted. While the oral route is typically a prelude to IV insertion and deeper sedation, for procedures in which some degree of motion can be tolerated, adequate sedation may be achieved with oral use alone.<sup>52</sup> Significant adverse events, including bradycardia, hypotension, and respiratory depression, have not been reported.

A potential issue with administration via the oral route is bioavailability, as gastric absorption is poor (16%) while absorption across the oral or buccal mucosa is high (82%). Successful use of this route, then, depends on minimizing the amount of drug swallowed. Strategies to accomplish this include, as with IM administration, use of the undiluted IV formulation to minimize volume administered. Slow administration of the medication (drop by drop against the buccal mucosa or gum line) in doses of 1 to 1.5 µg/kg should also decrease swallowing but requires patience and some degree of child cooperation. Success with this may be improved by having a parent hold the child and slowly drip the solution under the tongue or between the lower lip and gum. Fortunately, palatability of this formulation does not appear to be problematic, which should facilitate patient cooperation during administration. Additional research is necessary to further delineate the feasibility and application of the oral or buccal route for procedural sedation.<sup>54,55</sup>

Due to administration challenges, interest in intranasal administration is growing. Bioavailability following administration of 1 µg/kg is similar to buccal administration (approximately 70%). Onset of sedation is dose dependent, with maximum sedation generally being observed 30 to 45 minutes following doses of 1 to 2 µg/kg, although some patients may require up to 60 minutes. Duration of sedation is longer with higher doses, lasting up to 90 minutes with the 2-µg/kg dose. Compared with buccal administration, equal doses of intranasal dexmedetomidine have been reported to have a more

rapid onset of action and produce deeper sedation and less anxiety at parental separation.<sup>54</sup> Intranasal administration was also considered to be more acceptable. When dexmedetomidine is used as a sole agent for procedural sedation, it has been recommended that higher doses are needed than those used for anesthesia premedication. Moderate to deep sedation is fairly consistently achieved with doses of 3 to 4  $\mu\text{g}/\text{kg}$  in older infants and toddlers and 2  $\mu\text{g}/\text{kg}$  in infants younger than 6 months. Duration of effective sedation is 45 to 60 minutes, making this an attractive option for procedures such as CT imaging, limited MRIs, and EEGs. The average recovery time is 90 minutes.

Despite these options, IV administration remains the most common route for dexmedetomidine. When used intravenously, the formulation is diluted in 0.9% saline to a final concentration of 4  $\mu\text{g}/\text{mL}$ . Initial studies reported induction and maintenance infusion doses of 0.5 to 1  $\mu\text{g}/\text{kg}$  and 0.5 to 1  $\mu\text{g}/\text{kg}/\text{h}$ , respectively, although sedation was not always adequate and supplementation with other agents was occasionally required.<sup>56–58</sup> Subsequent reports have consistently shown that sedation success is improved (success rates of 98%–99%), with higher induction doses (2–3  $\mu\text{g}/\text{kg}$ ) and maintenance infusion rates (1.5–2  $\mu\text{g}/\text{kg}/\text{h}$ ).<sup>59–61</sup> Additionally, despite higher doses, the adverse effect profile has remained limited. Most commonly, dexmedetomidine is administered as an induction bolus followed by an infusion. To avoid significant bradycardia or sinus pause, the induction dose can be given over a minimum of 5 to 10 minutes, although more rapid administration is common in clinical practice. Induction may be achieved in different ways. Some practitioners routinely administer a planned induction dose of 2 to 3  $\mu\text{g}/\text{kg}$  to all patients. Others prefer to titrate the induction via manual administration of 1  $\mu\text{g}/\text{kg}$  bolus doses every 5 to 10 minutes until sedation is achieved or by initiating an infusion at 12  $\mu\text{g}/\text{kg}/\text{h}$  (1  $\mu\text{g}/\text{kg}$  every 5 minutes) until the patient is asleep and then decreasing the infusion to a maintenance rate. With any of these induction strategies, sedation is typically achieved in 10 to 15 minutes and clinically effective sedation lasts for 45 to 60 minutes. Thus, for studies lasting less than 30 to 40 minutes, an infusion may not be necessary or repeat doses of 0.5 to 1  $\mu\text{g}/\text{kg}$  may be administered if needed. For longer studies, use of a maintenance infusion of 1 to 3  $\mu\text{g}/\text{kg}/\text{h}$  following induction is more convenient. Unless significant stimulation will occur during the procedure, this infusion may be discontinued 5 to 10 minutes prior to the completion of the procedure to decrease recovery time, which is typically 30 to 60 minutes following discontinuation of the

infusion.<sup>57,58,60,61</sup> Despite anecdotal experience suggesting the safety of higher dosing regimens (2–3 µg/kg), these regimens have not had adequate systematic investigation. Although blood pressure was reportedly maintained, heart rate values of 30 to 50 beats per minute were reported in these studies. Although these higher doses achieved increased efficacy with completion of the procedure without addition of a second agent, it may be preferable to consider adding ketamine or midazolam to the dexmedetomidine regimen to limit the dosing requirements.

One of the most quoted advantages of dexmedetomidine is minimal associated respiratory depression.<sup>58–60</sup> Additionally, dexmedetomidine seems to affect upper airway morphology less than other sedative agents, which may make it an attractive option for the child with a history of, or who is at risk for, airway obstruction during sedation, including patients with obstructive sleep apnea.<sup>62,63</sup> The most common adverse effects reported with dexmedetomidine are cardiovascular, especially bradycardia and hypotension, although self-limited hypertension during induction is also not infrequent. Bradycardia seems to be relatively more common than hypotension and can be significant, especially when other heart rate-decreasing medications such as digoxin are present or in patients with preexisting conduction disturbances.<sup>64,65</sup> While rarely requiring intervention, care should be used if treating bradycardia with anticholinergics such as glycopyrrolate, as this may be associated with development of profound hypertension.<sup>66</sup> Similarly, hypotension is usually mild, has a vasodilator origin, and responds well to fluid administration, although intervention is not usually necessary.

More recently, there has been increased interest in combining dexmedetomidine with ketamine for procedural sedation.<sup>67</sup> This practice has been encouraged not only by concerns about potential hemodynamic effects of dexmedetomidine but also other issues, including the lack of analgesic effects of dexmedetomidine, making it less than perfect for invasive procedures, as well as the somewhat prolonged induction times that may be required with administration of the bolus dose over 10 to 15 minutes. Advantages of this combination would be that the sympathomimetic effects of ketamine would blunt dexmedetomidine-associated sympathectomy and associated bradycardia and hypotension. The analgesic properties of ketamine would allow for the use of this combination for painful procedures, and the rapid onset of ketamine would allow for the more rapid induction of sedation.

Additionally, the central effects of dexmedetomidine would limit development of post-ketamine emergence delirium.

The addition of ketamine (0.75–1 mg/kg) just prior to dexmedetomidine administration significantly increases sedation induction rapidity while blunting the development of bradycardia or hypotension, although this latter benefit seems to diminish as the duration of dexmedetomidine infusion increases.<sup>67</sup> Another option is to coadminister the induction dose of dexmedetomidine (1–2 µg/kg) with ketamine over a shorter period (2–3 minutes), followed by dexmedetomidine infusion (1–2 µg/kg). Additional bolus doses of ketamine (0.5 mg/kg) can be administered as needed. The induction dose of ketamine and dexmedetomidine can even be mixed in the same syringe (ketamine 0.5–1 mg/kg with dexmedetomidine 1 µg/kg). This regimen can be used for non-painful as well as painful procedures. With this regimen, we have not observed ketamine-associated emergence delirium. The recovery-related agitation described with other agents, especially chloral hydrate and barbiturates, does not appear to occur with dexmedetomidine when used alone or in combination with ketamine. This has been noted even when used in populations at high risk for these behaviors, such as children with autism spectrum disorder or other neurobehavioral disorders.<sup>61</sup>

## Etomidate

Etomidate is an imidazole, nonbarbiturate, GABA-mediated sedative-hypnotic agent that was introduced into clinical practice in 1972. It has potent sedative and amnestic properties but provides no analgesia. Due to its rapid onset of action, favorable hemodynamic profile, and intracranial pressure-reducing effects, it has been a popular agent in emergency departments, the operating room, and intensive care units for rapid sequence intubation of the trachea.<sup>68</sup> In the past decade, interest has grown in expanding use to the procedural sedation arena. Reports have described use as a sole agent for short, noninvasive procedures, such as CT scans, and as an adjunct sedation for painful procedures, such as fracture reductions.<sup>69–72</sup> Dosing is similar if used for sedation alone or in conjunction with an analgesic. Sedation is induced with 0.2 mg/kg IV, with subsequent doses of 0.1 mg/kg every 2 to 3 minutes if needed. The median effective dose is approximately 0.3 mg/kg.<sup>69,70</sup> Sedation onset is rapid, occurring within 5 minutes, and recovery time is relatively short with most patients returning to baseline within 20–25 minutes.

Adverse effects are relatively common, although most are minor. The most frequent events are pain on injection (up to 40%); brief, self-limited myoclonus (22%–25%); and post-sedation nausea and vomiting (8%–10%). Osmolarity of the solution and diluent, propylene glycol, results in pain and the potential for thrombophlebitis with administration through a peripheral vein. While myoclonus would likely be a greater detriment during sedation for CT or MRI because of associated motion artifact, it appears to be a significantly more common finding when etomidate is used as an adjunct sedative for painful procedures (22%–25%) than when used alone (4%). When used as a sole agent, clinically significant respiratory depression is uncommon (0.2%). However, this incidence increases to 15% to 20% when combined with an opioid.<sup>71,72</sup> With lower dosing protocols (0.1 mg/kg doses), sedation failures are not uncommon (up to 25%) but decrease to less than 1% when higher doses (0.3 mg/kg) are used. For painful procedures, the quality of sedation with etomidate-fentanyl is reported to be superior to that achieved with midazolam-fentanyl but inferior to midazolam-ketamine.<sup>71,72</sup> Although still used in the critically ill patient for endotracheal intubation, the major issue that currently limits the use of etomidate are concerns about its effects on the endogenous production of corticosteroids.<sup>73</sup> Given this concern, the issues outlined previously, and the availability of several other agents, there remains limited interest in the use of etomidate for most procedural sedation scenarios.

## Propofol

Propofol is an IV anesthetic agent with potent sedative and hypnotic but no analgesic properties. The specific mechanism of action by which these effects are mediated remains unclear but appears to involve GABA<sub>A</sub> potentiation and sodium-channel blockade. Due to its rapid onset of action and short recovery time, it has become the most popular primary agent used by pediatric procedural sedation practitioners.<sup>74,75</sup> Applications are broad and include use as a solitary agent for noninvasive procedures or in combination with an analgesic for painful or invasive procedures.<sup>74–78</sup> Due to poor solubility in water, propofol is produced as a lipid emulsion in a 1% solution (10 mg/mL). Components of this lipid include soybean oil, glycerol, and egg lecithin. In addition, an antimicrobial agent is added. Different manufacturers use different antimicrobials, including ethylenediaminetetraacetic acid (EDTA), benzyl alcohol, and sodium metabisulfite. These have limited effect on the

pharmacodynamics of propofol, although they may affect the complaint of pain with administration.

Given the lipid component, concern has been expressed about the use of propofol in patients with allergies to egg, soybean, or peanut. Some have suggested the use of alternative agents in such populations, while others have reported the safe use of propofol provided that the patient does not have true anaphylaxis from these agents.<sup>79–82</sup> Current data suggest that peanut allergy should not be considered as a contraindication to the administration of propofol. The risk of cross-reactivity between soy and peanut has been reported at less than or equal to 5%. Avoidance of peanut is not recommended among children with soy allergy given the low cross-reactivity between the proteins. A retrospective study reported no allergic manifestations following propofol administration to children with peanut allergies.<sup>79</sup> For patients with a soy allergy, the soy oil component is unlikely to contain significant enough amounts of protein to illicit an allergic response.

Regarding egg allergy, data are less clear. Propofol contains egg lecithin, which is derived from egg yolk. Egg allergy is most commonly associated with the egg-white protein, ovomucoid, and other proteins found in the egg white. On quantification of egg protein contained in egg lecithin, it has been reported that all protein is derived from egg yolk and at very low levels (0.005% or 50 ppm). There was one non-anaphylactic allergic reaction to propofol among 28 children with egg allergy who received propofol.<sup>79</sup> The issue is further confounded by inconsistencies among manufacturers and their package labeling. The drug labeling for Diprivan (Fresenius Kabi, Lake Zurich, IL) states: “Diprivan Injectable Emulsion is contraindicated in patients with allergies to eggs, egg products, soybeans or soy products.” However, a different manufacturer (AstraZeneca Pharmaceuticals, Wilmington, DE) does not provide such a warning. In conclusion, there does not appear to be scientific basis for suggesting the avoidance of propofol among children with a soy or peanut allergy only. Caution may be exercised specifically in patients with a history of true anaphylaxis to eggs.

A newer water-soluble prodrug, fospropofol (Lusedra), is also available. The drug is metabolized by hepatic alkaline phosphatase to the parent compound propofol following IV administration. As such, it has a longer onset time and is less potent than the parent compound. To date, there are no trials involving its use in the pediatric population.

The rapid onset of action of propofol is due to its highly lipophilic nature, while rapid peripheral distribution accounts for the short recovery times observed. Additional advantages of the drug are modest antiemetic properties and a decrease in intracranial pressure associated with a reduction in cerebral metabolic rate for oxygen, which make propofol an attractive choice for sedation of patients in whom concerns for intracranial hypertension exist.<sup>83,84</sup> The latter effect on intracranial pressure occurs only if mean arterial pressure and arterial carbon dioxide are unchanged.<sup>85</sup>

For all but the shortest procedures, propofol is generally administered as a bolus induction followed by infusion. While individual responses vary, deep sedation is typically achieved following total doses of 1 to 2 mg/kg (administered in incremental doses of 1 mg/kg each). If this is insufficient, additional boluses of 0.5 to 1 mg/kg may be administered every 1 to 2 minutes as needed and titrated to effect. For brief procedures, a strategy of intermittent boluses is often adequate and practical because it does not require preparation and initiation of an infusion. However, for longer procedures or those in whom patient access is limited, repetitive bolus dosing is impractical and induction followed by an infusion is generally preferred. Maintenance infusion doses of 2 to 5 mg/kg/h (120–300 µg/kg/min) are typical and may be rapidly titrated during the procedure.<sup>77,86</sup> Of note, infants appear to require higher doses than older children but are also at an increased risk of associated respiratory depression, so added vigilance should be practiced when using propofol in this population. Although propofol is effective in providing procedural sedation, it should be appreciated that the depth of sedation achieved is almost always deep sedation. In fact, in the few studies that have used depth of anesthesia monitoring, the level achieved is equivalent to general anesthesia in most cases.<sup>87</sup>

For painful procedures (eg, lumbar punctures, fracture reductions), the addition of an analgesic agent should be strongly considered. Alternatively, as with other agents with purely sedative properties, liberal use of topical and local anesthetic agents may be effective in preventing pain from an invasive procedure or needlestick (see Chapter 10). Opioids are the most commonly used analgesic adjunct, with fentanyl (1–2 µg/kg) being the preferred agent because of its short duration of action. Other short-acting opioids, including alfentanil (20 µg/kg) or remifentanyl (0.5–1.5 µg/kg bolus ± infusion of 0.1 µg/kg/min), have also been successfully used, although clinically important respiratory depression requiring more aggressive intervention

is not uncommon.<sup>88–90</sup> In an attempt to limit the incidence of respiratory depression, the combination of ketamine-propofol has become increasingly popular.<sup>91–93</sup> In these applications, ketamine (0.5–1 mg/kg) is generally administered prior to propofol induction, with propofol dosing being similar to when propofol is used as the sole agent. While data are mixed as to the effect of this regimen on overall respiratory events, they consistently demonstrate improved hemodynamic stability compared with propofol alone. While emergence reactions may still occur if using this combination for very short procedures, it is associated with less post-sedation nausea and vomiting compared with ketamine alone. In addition to its use in individual syringes, propofol and ketamine are also commonly mixed into one solution, commonly called “ketofol.”<sup>94</sup> This combination remains a popular mixture for various invasive and noninvasive procedures. Various mixture concentrations have been used with a propofol to ketamine ratio varying from 1:1 to 5:1 with the suggestion that the higher propofol to ketamine ratio may be preferable in terms of the adverse effect and recovery profiles.<sup>95</sup> Despite its common use in clinical practice, there are limited data on compatibility of these agents when they are mixed in a single solution. Additionally, when such mixtures are used, dosing errors may result from mathematical errors, suggesting that it is imperative to have such mixtures double-checked by a second practitioner.

Adverse effects associated with propofol are similar to those associated with other sedatives. Cardiovascular depression and hypotension, related to negative inotropic and vasodilator properties, are frequent but generally transient, and the need for intervention is infrequent.<sup>96</sup> The hemodynamic depression may be accentuated in patients with comorbid conditions or with concomitant administration of other agents, including opioids, thereby making propofol a less than optimal choice for patients with depressed myocardial function or those with aortic or mitral stenosis who may not tolerate the rapid decrease in systemic vascular resistance. Respiratory events are also not uncommon and include central depression (apnea) as well as airway obstruction, laryngospasm, and hypoxemia.<sup>74</sup> These occur most commonly with bolus induction doses. Because of rapid dissipation of its effects, prolonged respiratory depression does not appear to occur, and the need for more than brief bag-valve-mask support is very rare. Less common CNS effects include myoclonus and epileptogenic-like activity despite propofol having anticonvulsant properties.<sup>97</sup> While it does not usually interrupt the procedure, pain



on injection is relatively common with propofol and can be distressing to parent and child. Strategies to diminish this problem include pretreatment with small doses of lidocaine (0.2–0.5 mg/kg), fentanyl (0.5–1 µg/kg), or ketamine (0.25–0.5 mg/kg).<sup>98–100</sup>

## Summary

Sedation practitioners today have a variety of sedative options available to facilitate pediatric sedation. While no single agent is adequate or appropriate for all patients or procedures, it is also true that multiple regimens may be appropriate for any given patient. The specific choice of agent or regimen for any patient should, ideally, match the pharmacology of the agents used with the needs of the procedure and underlying patient health status and comorbidities. However, it will also depend on which agents the practitioner has available and his or her clinical experience and comfort level. Regardless of the choice made, a high degree of preparedness and vigilance for adverse event development must be present during every sedation encounter, as serious complications and morbidities may occur with any of the agents described herein. Furthermore, familiarity with several agents allows the practitioner to add alternative agents should the first-line choice prove ineffective.

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CHAPTER 6

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## **Medications Part 2: Ketamine, Nitrous Oxide, and Opioids**

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### **Introduction**



Procedural sedation involves noninvasive (painless) and invasive (painful) procedures. Although there are many options for sedation during painless procedures, agents with analgesic properties are generally included in the sedation regimen for invasive or painful procedures. In doing so, these agents not only provide effective analgesia but also limit the doses required of agents that possess solely sedative actions. This dose limitation is beneficial because the adverse effects of these agents, including respiratory depression, are dose dependent. This chapter reviews agents that are commonly used to provide analgesia during procedural sedation, including ketamine, nitrous oxide, and opioids.

In most scenarios, these agents are combined with a sedative agent (eg, propofol, midazolam, dexmedetomidine) to facilitate the performance of a painful procedure. In other circumstances, the hemodynamic effects of the 2 agents can be used to offset the potential deleterious consequences of one agent. Examples of this include the use of ketamine with dexmedetomidine to not only provide sedation and analgesia but to also lessen the incidence and degree of bradycardia, or the combination of ketamine and propofol to offset the hypotension associated with propofol.<sup>1,2</sup>



In addition to ketamine and opioids, this chapter also reviews application of the commonly used inhaled anesthetic agent nitrous oxide. Although used most commonly as a sedative or analgesic agent during dental procedures, there has been increased use of this agent in emergency and radiology departments as well as by procedural sedation services. Given its rapid onset and delivery via the noninvasive inhalational route, it has developed a unique niche in the arena of procedural sedation.

## Ketamine

### Introduction

Ketamine was introduced into clinical practice more than 50 years ago.<sup>3</sup> Ketamine creates a unique state of sedation referred to as *dissociative anesthesia*. This anesthetic state is characterized by patients who frequently keep their eyes open during a procedure and yet are unresponsive to painful stimuli. Given this unique sedative state, as noted in Chapter 1, the American College of Emergency Physicians has proposed that ketamine sedation be considered outside of the sedation spectrum described by the American Academy of Pediatrics (AAP). The American College of Emergency Physicians has proposed adding the category of dissociative sedation to guidelines that also include separate descriptions of *minimal sedation*, *moderate sedation*, *deep sedation*, and *general anesthesia*. To date, none of the other major specialty physician groups or regulatory bodies have adopted this separate categorization.

### Chemical Structure and Pharmacology

The chemical structure of ketamine contains a chiral carbon, thereby resulting in 2 optical isomers, (S)+ and (R)-. The preparation currently used most commonly in clinical practice in the United States is a racemic mixture of these optical isomers. Outside of the United States, the single (S)+ enantiomer is available for clinical use. Although the initial literature on this agent was quite favorable when comparing it with the racemic mixture, this has not necessarily been shown to be the case, and enthusiasm for its use has waned.

In addition to the unique dissociative sedation state produced by ketamine, there are additional differences when compared with other procedural sedation agents. Ketamine is unique in that it possesses analgesic and amnestic properties that result from poorly defined mechanisms within the limbic and thalamic systems. Additional sites of action include antagonism of the *N*-methyl-D-aspartate receptor as well as agonism at the  $\mu$  opioid receptor. Commercially available ketamine is produced in concentrations of 10 mg/mL (1%), 50 mg/mL (5%), and 100 mg/mL (10%). Although this allows flexibility as far as using the dilute solution for intravenous (IV) titration and the concentrated solution for intramuscular (IM) administration, care must be taken, as it also sets the stage for 10-fold overdosing when incorrect concentrations are used.

Metabolism of ketamine occurs through hepatic *N*-methylation to the active metabolite, norketamine. Altered metabolism and clearance of ketamine may occur in patients with hepatic dysfunction, thereby necessitating dose alterations when repeated doses or infusions are used. Norketamine retains one-third of the analgesic and sedative properties of the parent compound; it is water soluble and undergoes renal elimination. As such, dose adjustments may also be required in the presence of renal dysfunction. Bioavailability of ketamine is 100% following IV or IM administration but is markedly decreased with oral or rectal administration because of limited absorption and a high degree of first-pass hepatic metabolism.

Ketamine's popularity as an agent for procedural sedation lies in its reliability, analgesic properties, and limited effects on physiologic function, as well as other beneficial properties and features (Box 6-1). In general, it does not suppress spontaneous ventilation, pharyngeal function, or protective airway reflexes. However, in patients with significant comorbid respiratory or hemodynamic compromise, adverse effects may occur.<sup>4,5</sup>

#### **Box 6-1. Beneficial Features and Properties of Ketamine**

1. Provides analgesia, sedation, and amnesia
2. Limited hemodynamic effects
3. Limited respiratory effects
4. Alternative routes of delivery in addition to intravenous administration
5. Relatively brief duration of action following a single bolus dose
6. Limited cost

Dosing Regimens and Routes of Administration

The ideal patient would be a child older than 12 months, who has fasted for at least 6 hours, requiring sedation for a relatively brief, yet painful, procedure.<sup>6</sup> Typical procedures include lumbar puncture, bone marrow aspirate or biopsy, laceration repair, fracture reduction, and application of burn dressings. Therefore, ketamine is used frequently by emergency physicians in emergency departments and by hospital-based sedation services. In these settings, following placement of an IV cannula, a typical dosing regimen would include an initial bolus dose of 1 mg/kg followed by incremental doses of 0.5 mg/kg, which are administered as needed every 1 to 2 minutes until the desired dissociative state is achieved. In most cases, 1 to 2 mg/kg are required to provide effective analgesia and sedation for brief, painful procedures. Higher doses with repeated dosing may be needed for more prolonged procedures. Adjunctive agents to prevent emergence delirium (midazolam) or emesis or to dry secretions (atropine or glycopyrrolate) may also be used. An alternative dosing regimen is a single IM ketamine dose of 3 to 4 mg/kg. If adjuvant (midazolam/atropine) agents are added to the IM regimen, they may be mixed with the ketamine in the same syringe. This would obviate the need for placement of an IV cannula (Table 6-1).

Although alternative routes (eg, oral, intranasal, buccal, per rectum) of ketamine delivery have been reported, in everyday clinical practice, these alternative routes will have a limited role. Oral or intranasal administration of ketamine is occasionally chosen when IV access is not present and the patient’s anxiety or cognitive level precludes placement of an IV cannula with a topical anesthetic cream.<sup>7,8</sup> When these routes are chosen, problems exist with the diluent of the IV preparation, which may burn with intranasal administration or make the solution distasteful for oral administration.

Table 6-1. Comparison of Intravenous and Intramuscular Ketamine

Route of Administration	Intravenous	Intramuscular
Initial dose	1–2 mg/kg	3–5 mg/kg
Onset of action	1 min	5 min
Duration of single dose	Up to 15 min (prolonged with multiple doses or infusion)	15–45 min
Recovery	1–2 h	3–4 h

## End-Organ Effects

Since its introduction into clinical practice, there has been much press and discussion given to the potential adverse effect profile of ketamine. Adverse effects include vomiting, secretions, laryngospasm, emergence reactions (hallucinations), and hemodynamic effects (ie, tachycardia, hypertension, and increased pulmonary vascular resistance [PVR]) and its potential effects on intracranial pressure (ICP). The most commonly reported side effect is vomiting, with a reported incidence that varies from 3.5% up to 28%. A higher incidence is reported with IM administration.<sup>9,10</sup> Given the relatively high incidence of emesis, various prophylactic approaches at prevention have been evaluated. Neither anticholinergic agents (atropine) or motility agents (metoclopramide) have been shown to decrease the incidence of vomiting.<sup>11</sup> The 5-HT<sub>3</sub> antagonist, ondansetron (Zofran), decreased the incidence of vomiting in the emergency department or after discharge home from 18.9% to 7.8%.<sup>12</sup> Premedication with midazolam has also been shown to decrease the incidence of emesis but perhaps at a greater risk of respiratory depression and prolonged sedation.

With everyday clinical use, the adverse effect of ketamine that continues to attract the most attention and stimulate the most debate is the development of emergence phenomena or hallucinations. In an effort to minimize the likelihood of emergence reactions, clinical practice may include pharmacologic (midazolam) or environmental measures along with or prior to the administration of ketamine. Emergence reactions occur in 7% to 10% of patients, usually as they are recovering from sedation. These reactions are more frequent in older patients, especially adolescents and young adults. Manifestations include confusion, hallucinations, delirium, erratic behavior, and unusual dreams. These manifestations may be avoided by creating a relaxing and soothing environment for the patient before, during, and after the procedure. Adjustments to the environment may include distraction with stories or music, positive imagery, dim lights, and a decreased noise level in the room. Institutions with child-life programs often use personnel from these programs to help set the right mood for the anticipated sedation. Benzodiazepines (typically midazolam) have been the mainstay of pharmacotherapy, with the implication that premedication or prophylactic intervention produces slightly better results than treatment after the problem has occurred.<sup>13</sup> Other agents that may decrease such problems and can be coadministered with ketamine include propofol and dexmedetomidine. However,

studies have demonstrated that the routine addition of the adjunctive agent midazolam has no advantage over relaxation techniques and may increase the risk of respiratory depression associated with the sedation.<sup>14,15</sup>

Additional controversy surrounds ketamine and its effects on the central nervous system, including ICP and the seizure threshold. Historically, ketamine was avoided in patients undergoing a lumbar puncture requiring opening pressure and in patients with or at risk for intracranial hypertension (elevated ICP), such as trauma patients or patients with intracranial masses or hydrocephalus. However, recent data from animal and human studies have shown no change or even a decrease in ICP following ketamine administration, especially when it is coadministered with a benzodiazepine or propofol.<sup>16,17</sup> Speculation is that previous results of studies from the 1970s and 1980s, which suggested an increase in ICP following ketamine administration, were related to alterations in  $Paco_2$  and not a direct effect of the medication itself. Although ketamine may have limited effects on ventilatory function, caution is still advised when treating patients at risk for elevated ICP, as even minor changes in ventilation and the resultant hypercapnia may affect ICP. However, when a patient's ventilation is controlled, clinical practice with ketamine is changing. In our institution, ketamine is now part of the endotracheal intubation protocol for critically ill medical and trauma patients, even for those patients with suspected intracranial injury and altered intracranial compliance.

Another frequently cited yet unproven relative contraindication to ketamine is the presence of a seizure disorder. Although electroencephalogram recordings during ketamine administration demonstrate increased frequency and amplitude with occasional paroxysmal seizure activity, no clinical evidence of seizure activity has been reported with ketamine administration. Studies in laboratory animals have demonstrated anticonvulsant effects of ketamine, while anecdotal experience suggests that ketamine can be used to treat refractory status epilepticus.<sup>18–20</sup>

Despite its generally favorable effects on respiratory function and upper airway protective reflexes, including the provision of bronchodilation due to the release of endogenous catecholamines, adverse effects on upper airway function and even laryngospasm may occur following ketamine administration. These, in part, relate to the production of increased salivation and airway secretions. These effects have prompted the suggestion that ketamine should be coadministered with an anticholinergic agent such as atropine (0.01 mg/kg)

or glycopyrrolate (0.005 mg/kg). However, recent studies demonstrate that the actual risk of hypersalivation is low and that the use of these adjunct medications may be unnecessary.<sup>21–23</sup> However, this debate is far from resolved, as other authorities suggest that an anticholinergic agent is indicated with the use of ketamine.<sup>24</sup> Hypersalivation may provoke laryngospasm or a forced closing of the vocal cords, which prevents airway exchange. The incidence of airway problems such as laryngospasm is higher when there is history of an antecedent upper respiratory infection and perhaps in those patients chronically exposed to tobacco smoke. When laryngospasm occurs, treatment must be instituted promptly to reestablish airway exchange and prevent hypoxemia and its clinical consequences. Treatment strategies include implementation of appropriate airway maneuvers, including a triple airway maneuver (ie, chin lift, head tilt, and jaw thrust) and the application of continuous positive airway pressure. If laryngospasm fails to resolve, administration of a rapid-acting neuromuscular blocking agent (eg, succinylcholine, rocuronium) may be required. Successful reversal of laryngospasm has also been reported with application of medial and anterior pressure at the laryngospasm notch.<sup>25</sup> The notch is located in the soft tissue just behind the earlobe, posterior to the angle of the mandible and inferior to the base of the skull. For unknown reasons, this noxious stimulus causes a sudden inspiratory effort or gasp, thereby breaking the laryngospasm.

Two additional effects of ketamine deserve attention: its potential to depress myocardial function and its effects on PVR. Due to endogenous catecholamine release, ketamine increases heart rate and blood pressure in most patients. These indirect sympathomimetic effects tend to compensate for its direct negative inotropic properties. However, in patients who are catecholamine depleted due to severe acute or chronic comorbid conditions, direct negative inotropic properties of ketamine may predominate and lead to myocardial depression or even hemodynamic collapse.<sup>26,27</sup>

Concern has also been expressed about the effect of ketamine on PVR and its use in patients with pulmonary hypertension. Although initial studies suggested that ketamine might elevate PVR, these studies were generally performed without full ventilatory support and control of  $\text{PaCO}_2$ , thereby making it impossible to separate the direct effects of ketamine from secondary effects related to changes in ventilation.<sup>28</sup> Most recently, no direct effect of ketamine on PVR was noted even in patients with preexisting pulmonary hypertension.<sup>29</sup> The safety of ketamine in patients with congenital heart

disease is further evidenced by experience with its use during spontaneous ventilation for sedation during cardiac catheterization. In this patient population, incidence and severity of hypotension have been noted to be less with ketamine than with propofol.<sup>30</sup> However, given the significant risk of morbidity and even mortality with comorbid diseases such as congenital heart disease or pulmonary hypertension, endotracheal intubation and control of ventilation may be indicated in such patients. Consultation with a pediatric anesthesiologist may be indicated in such patients.

Although frequently used as the sole agent or in combination with a benzodiazepine such as midazolam, there is a trend in clinical practice to combine ketamine with other agents, such as propofol or dexmedetomidine.<sup>2,31–33</sup>

The goal of such combinations is to use the desirable aspects of each medication while decreasing the adverse effect profile. For example, propofol combined with ketamine provides excellent sedation with decreased emesis, fewer adverse hemodynamic effects, and faster recovery times when compared with ketamine alone. The addition of ketamine to a sedation regimen using propofol provides analgesic effects that are lacking with propofol alone. This can be done by using separate infusions or mixing propofol and ketamine together in a single 10-mL syringe.<sup>2</sup> Various recommendations have appeared in the literature on the mixture of propofol and ketamine in a single syringe. While initial reports suggested using a 1:1 mixture, more recent clinical data have suggested lower concentrations of ketamine (1:4 or 1:5 ketamine to propofol) to limit propofol infusion requirements without affecting recovery times.<sup>2</sup> When such a practice is adopted, we would recommend an institution-based protocol with involvement of pharmacy to avoid medication errors. The lipophilic-hydrophilic nature of the solution may result in unequal distribution of medications in the syringe or alterations in bioavailability of the individual medications. Given the depth of sedation that is generally achieved with this combination (deep sedation or even general anesthesia), close monitoring of hemodynamic and respiratory function is mandatory.

Specific contraindications to ketamine sedation include hypersensitivity to ketamine or any component of ketamine. Ketamine induces dissociative analgesia; as such, parents should be warned that patients may keep their eyes open during the procedure and develop nystagmus. With IV administration, patients may complain of a bad or metallic taste. Although uncommon in the pediatric-aged population, ketamine should not be used

in patients who will not tolerate sudden increases in heart rate or blood pressure. Relative contraindications include a difficult airway, active upper respiratory infection with increased secretions, a history of a previous emergence reaction, or history of psychosis or behavioral disturbance. As with any sedative agent, ketamine should be used with caution in patients with significant comorbid conditions, those who do not meet nil per os guidelines, patients with hepatic dysfunction, or those with significant gastroesophageal reflux.

With these caveats in mind, ketamine remains a valuable agent for sedation during painful procedures. In all circumstances, adherence to the sedation and monitoring guidelines of the AAP is recommended.<sup>6</sup> Procedural sedation with ketamine should take place in a room that is specific for sedation. This room should be big enough for all practitioners taking part in the sedation (typically the sedating physician, procedure physician, and monitoring personnel), required equipment, and parents, if allowed per institutional policy. The room should be equipped with emergency airway resources (eg, oxygen, suction, bag-valve-mask device) and have access to resuscitation medications and age- and size-appropriate equipment. The patient should be on a continuous cardiorespiratory monitoring system throughout the sedation and recovery periods. The room should be able to provide a quiet, soothing setting that creates the ideal environment for ketamine sedation. Discharge criteria are often institution specific, but generally the patient should be awake enough to follow commands, have appropriate verbal responses, and be able to ambulate if appropriate. As noted previously, caution is advised given the availability of ketamine in various concentrations (10, 50, and 100 mg/mL). Ketamine remains a drug of abuse. As such, it needs to be tracked in the same manner as opioids and other sedative and analgesic agents.

## Nitrous Oxide

### Introduction

Nitrous oxide (chemical structure  $N_2O$ ) is a colorless gas that remains a common component of the intraoperative anesthetic regimen in many operating rooms throughout the world. When used in clinical practice,  $N_2O$  is supplied from the hospital central gas supply or cylinders where it is stored as a



liquid under pressure. As a safety feature, the tanks, outlets, and hoses used to administer medical gases are color coded in the United States ( $\text{N}_2\text{O}$  = blue, oxygen = green, air = yellow). An additional safety feature is a pin indexing system, so that an  $\text{N}_2\text{O}$  tank cannot be connected to a site meant for another gas. A unique aspect of  $\text{N}_2\text{O}$ , which may make it particularly valuable for procedural sedation, is its administration via the respiratory tract. Given its relative insolubility in blood and fat,  $\text{N}_2\text{O}$  has a rapid onset and a short duration of action on discontinuation. Although  $\text{N}_2\text{O}$  provides sedation, amnesia, and analgesia in a dose-dependent manner based on its inhaled concentration, its relative potency is low. However, it can be used as a sole agent for brief and mildly painful procedures, such as placement of an IV cannula.

Potency of inhalational anesthetic agents is defined by using the parameter minimum alveolar concentration, which is defined as the expired concentration (MAC) or percentage of the inhalational anesthetic agent that will prevent movement in response to a surgical stimulus in 50% of patients. Nitrous oxide has a MAC greater than 100% and therefore, even when breathing 70%  $\text{N}_2\text{O}$ , many patients will move in response to a surgical stimulus. Sub-MAC concentrations (30%–70%) of  $\text{N}_2\text{O}$  have been used successfully for procedural sedation, although they are frequently combined with other agents for more painful procedures.<sup>34</sup>

## End-Organ Effects

In general, practitioners may be drawn into a false sense of security with  $\text{N}_2\text{O}$  given its widespread use in many dental practices and reports of its safety with few, if any, adverse effects. In many of these reports, there was no monitoring of physiological function and no adherence to standard guidelines for procedural sedation. In these settings,  $\text{N}_2\text{O}$  is delivered using a nasal hood that fits over the nose, leaving the mouth free for dental work. Flow rates and delivery apparatus with entrainment of room air result in the delivery of less than 50%  $\text{N}_2\text{O}$ . However, there are significant end-organ effects (Box 6-2). Depending on the concentration administered,  $\text{N}_2\text{O}$  can be a sedative, anxiolytic, analgesic, or weak anesthetic agent. Concentrations of 70%  $\text{N}_2\text{O}$  (with 30%  $\text{O}_2$ ) will render most patients amnestic and provide moderate analgesia. Concentrations of 50% to 70% are generally effective for minor, painful procedures, such as placement of an IV cannula, voiding cystourethrogram, and reduction of a dislocated finger.

**Box 6-2. End-Organ Effects of Nitrous Oxide**

1. Central nervous system
  - a. Sedation and analgesia
  - b. Dysphoria
  - c. Increased cerebral blood flow and cerebral blood volume
  - d. Increased cerebral metabolic rate for oxygen
  - e. Altered cerebral autoregulation
  - f. Increased intracranial pressure with compromised intracranial compliance
2. Respiratory
  - a. Diffusion hypoxemia
  - b. Decreased minute ventilation (synergistic with other agents)
  - c. Impaired ventilatory drive to hypoxia
3. Cardiovascular
  - a. Depression of myocardial contractility
  - b. Stimulation of the sympathetic nervous system
  - c. Increased pulmonary vascular resistance
4. Hematologic and immune system
  - a. Impairment of vitamin B<sub>12</sub> metabolism
  - b. Suppression of immune function
5. Miscellaneous
  - a. Diffusion into and expansion of gas-containing spaces

Nitrous oxide has been reported to have significant physiological effects on cerebral dynamics, including cerebral metabolic rate for oxygen (CMRO<sub>2</sub>), cerebral blood flow (CBF), and ICP. In adults, N<sub>2</sub>O increases CBF, cerebral blood volume, and CMRO<sub>2</sub>; alters cerebral autoregulation; and may increase ICP, especially in patients with compromised intracranial compliance.<sup>34,35</sup> The relationship between N<sub>2</sub>O and CBF, CBV, CMRO<sub>2</sub>, ICP, and cerebral autoregulation are complex and at times contradictory in the literature. In spontaneously breathing patients with altered intracerebral dynamics or increased ICP, N<sub>2</sub>O should be avoided.

One of the more commonly discussed respiratory effects of N<sub>2</sub>O is diffusion hypoxia. As N<sub>2</sub>O is taken up from the alveolus, concentration of the other gases increases in direct proportion to the uptake of N<sub>2</sub>O. When N<sub>2</sub>O is discontinued, the gradient favors movement of N<sub>2</sub>O from the blood into the alveolus, thereby diluting out the oxygen, resulting in diffusion hypoxia. Given these concerns, supplemental oxygen should be administered during this time to limit the clinical effect of diffusion hypoxia. Nitrous oxide affects ventilatory drive, decreasing minute ventilation through a direct effect on the central control of ventilation. When administered alone and in the absence of comorbid diseases, N<sub>2</sub>O generally has limited effects on

ventilatory and cardiovascular function. Clinically, ventilatory effects are manifested by a decrease in tidal volume and an increase in respiratory rate. The more clinically significant respiratory effect of N<sub>2</sub>O on ventilatory function is a dose-dependent depression of the ventilatory response to hypoxemia. Nitrous oxide is relatively contraindicated in patients with chronic respiratory disorders who are dependent on hypoxemic drive. Synergistic respiratory depression has also been demonstrated clinically in the pediatric population when N<sub>2</sub>O is administered with oral chloral hydrate or midazolam.<sup>36–38</sup> In addition to its central ventilatory effects, upper airway obstruction may affect respiratory function, especially in children with adenotonsillar hypertrophy or obstructive sleep apnea. Reports reviewing the database of adverse sedation events from the US Food and Drug Administration noted that N<sub>2</sub>O was an independent risk factor for adverse events when administered with any other sedative agent.<sup>39,40</sup>

As with its effects on ventilatory function, cardiovascular effects of N<sub>2</sub>O may be modified by the patient's status and presence of comorbid disease processes. A mild decrease of blood pressure may be seen due to a depression of myocardial contractility as well as minimal decreases in heart rate and systemic vascular resistance. In many clinical scenarios, any direct negative inotropic effect on the myocardium or on the systemic vascular resistance is compensated by stimulation of the sympathetic nervous system. Of greater concern is the vasoconstrictive response and its effect on patients with pulmonary hypertension. Given the tenuous nature of patients with pulmonary hypertension and their increased risks of adverse effects and mortality during general anesthesia and sedation, N<sub>2</sub>O is generally not recommended in this population.

Additional physiological effects on neurologic and hematologic function may result from inactivation of enzyme methionine synthetase with issues relating to vitamin B<sub>12</sub> metabolism. These may affect not only the patient with repeated administration but also the health care professional who may be exposed during N<sub>2</sub>O administration. The latter mandates appropriate safety features to ensure effective scavenging and room ventilation. Although there are limited data to prove an association, it has been postulated that repeated exposure of health care professionals to N<sub>2</sub>O may lead to issues with infertility or increased rates of spontaneous abortion. All of these adverse effects may be significantly increased in patients with specific genetic metabolic defects of the homocysteine-methionine pathway, such as methylenetetrahydrofolate reductase.

In addition to appropriate scavenging equipment, other means to limit environmental contamination with  $N_2O$  include ensuring proper functioning of the delivery apparatus with a check of all fittings for leaks, adequate ventilation of the procedural area with appropriate air exchange rates (8–10 per hour), venting of the exhaust system to the outside of the building, effective mask fit on the patient with minimal leak, and administration of 100% oxygen for 3 to 4 minutes at the completion of the case to allow the patient to breath out residual  $N_2O$ .

Recent concern has also been raised about potential effects of  $N_2O$  on immune function and its relationship to perioperative surgical site infections,<sup>41</sup> although a causal relationship has not been conclusively demonstrated. The blood gas partition coefficient of  $N_2O$  is 0.46 or more than 30 times greater than that of nitrogen. When  $N_2O$  is administered instead of air,  $N_2O$  will enter gas-filled spaces more than 30 times faster than nitrogen can exit the space, resulting in an increase of volume and pressure within this space. Gas volume and pressure can become dangerously high within an obstructed bowel, pneumothorax, sinuses, pneumocephalus, or the middle ear. One of the most commonly cited adverse effects of  $N_2O$  is nausea and vomiting. This effect, which is dependent on dose and duration of administration, is less than that reported with opioids or volatile anesthetic agents and can be prevented by administration of an antiemetic agent such as a 5-HT<sub>3</sub> antagonist (Zofran) prior to commencement of the sedation.

## Delivery Techniques, Devices, and Masks

There are several mandatory safety features that should be included in the  $N_2O$  delivery system, which are best accomplished by use of a commercially available machine; the use of homemade delivery systems is not recommended. Safety features include mechanisms to prevent delivery of a hypoxic mixture, such as an in-line  $F_{IO_2}$  monitor, a fail-safe device to cut off  $N_2O$  flow if the oxygen supply fails, and a system to regulate the ratio of the flow rates of the oxygen and  $N_2O$  so that less than 30% oxygen cannot be delivered (proportioning device).

Nitrous oxide is delivered from a tank or directly from the hospital's central supply from outlets mounted in the wall. When  $N_2O$  is delivered from tanks, it may be administered as a fixed concentration from a single tank, generally a 50% concentration, or mixed from separate tanks, usually E cylinders. Although used extensively outside of the United States, single tanks with

a 50–50 mixture of  $N_2O$  and oxygen are not commercially available in the United States at this time. With the resurgence of interest in applications of  $N_2O$  for procedural sedation, new delivery devices have been introduced to the clinical market.<sup>34</sup> For example, Linde AG (Munich, Germany) markets the SEDARA Gas Mixer System, and Sedation Systems LLC (Clearwater, FL) has developed a device that incorporates a novel mask and breathing system into the  $N_2O$  delivery system.

In addition to the machine and circuit, some type of mask or other device is required for  $N_2O$  administration. In general, a tight seal should be provided by the airway interface device to allow effective delivery of  $N_2O$  without entrainment of room air. This will ensure that the set concentration equals the delivered concentration without environmental contamination. There are 2 common types of  $N_2O$  delivery systems, free flow and demand flow. Free flow uses a steady flow of  $N_2O$  with a reservoir bag to allow for deep inspiration. Demand flow delivery apparatus requires the patient to generate a negative inspiratory force of -2 to -5 cm  $H_2O$  to start and maintain  $N_2O$  flow. Demand flow devices are less likely to result in  $N_2O$  flow into the environment but may not work for younger children who are unable to generate an effective negative inspiratory force. One unique means of  $N_2O$  delivery that has seen significant use in clinical practice is a weighted mouthpiece or mask. These devices are most commonly used when  $N_2O$  is delivered as a fixed 50% concentration from a single tank. The mouthpiece or mask will fall away from the patient, thereby eliminating the delivery of  $N_2O$  if the patient becomes too sleepy and releases the mask. These types of devices are frequently used with circuits and delivery apparatus that require the patient to generate a negative inspiratory force of -2 to -5 cm  $H_2O$  to start and maintain  $N_2O$  flow.

## Summary

Despite potential concerns about delivery systems and end-organ effects of  $N_2O$ , there has been a resurgence in interest for this agent for procedural sedation, likely related to its ease of administration via a non-parenteral route that does not mandate IV access or an IM injection. Nitrous oxide has been shown to be effective for a variety of minor procedures, such as venipuncture, IV cannula placement, lumbar puncture, bone marrow aspiration, laceration repair, dental care, and minor dermatologic procedures.<sup>34</sup> It is

generally as effective as midazolam, with several studies demonstrating it to be even more effective.<sup>34</sup> It is less effective as a sole agent in moderately to severely painful procedures, such as fracture reduction or injection of botulinum toxin. Most patients have been noted to prefer N<sub>2</sub>O to other agents or agree to its use again for subsequent procedures. The literature and our clinical experience demonstrates increased success rates with simple procedures such as IV cannula placement when compared with no sedation or topical anesthesia alone. Nitrous oxide is generally more effective in older children ( $\geq 5$ –6 years), while younger children are more likely to resist application of the face mask and may even require physical restraint for mask application. For more painful procedures, combination with another agent should be considered and, if appropriate, topical or infiltrative local anesthesia is recommended. A full 3 minutes of administration may be required to achieve the maximum effect. Delivery technique and apparatus remain a major priority to ensure safety with the use of N<sub>2</sub>O (Box 6-3). Given the abuse potential of this agent, tanks must be kept under constant vision or locked away when not in use. A final issue with N<sub>2</sub>O for a procedural sedation program is who should be allowed to deliver it. Although classically thought of as an anesthetic agent, several centers have developed very successful programs with its administration by specially trained nurses.<sup>42,43</sup>

#### **Box 6-3. Safety Features for Nitrous Oxide Administration**

1. Prevention of health care professional exposure
  - a. Effective scavenging
  - b. Proper functioning of the delivery apparatus—check of fittings for leaks
  - c. Procedural area ventilation (air exchange rates of 8–10 per hour)
  - d. Venting of the exhaust system to the outside
  - e. Effective mask fit on the patient with minimal leak
  - f. Administration of 100% oxygen for 3 to 4 minutes at the completion of the case to allow the patient to breath out residual N<sub>2</sub>O
2. Machine features
  - a. In-line inspired oxygen concentration monitor
  - b. Fail-safe device (cuts off N<sub>2</sub>O flow if oxygen supply fails)
  - c. Proportioning device to ensure administration of at least 30% oxygen
  - d. Color coding of tanks
  - e. Pin indexing system
3. Full preparation and monitoring according to guidelines established for procedural sedation by the American Academy of Pediatrics

# Opioids

## Introduction

As a general class of medication, opioids are frequently used as an adjunctive agent during procedural sedation given their ability to reduce pain associated with certain procedures. In addition, opioids have synergistic sedating properties, which can also facilitate successful completion of the desired procedure. During the post-procedural phase, depending on the agent chosen, opioids may provide ongoing analgesia as the patient recovers and is discharged. This section on opioids focuses on those agent that may have some role in procedural sedation, including synthetic agents (ie, fentanyl and remifentanyl), hydromorphone (Dilaudid), morphine, and meperidine (Demerol).

## Mechanism of Action

Opioids act by binding to 1 of the 4 types of opioid receptors in the central or peripheral nervous system:  $\mu$ ,  $\kappa$ ,  $\delta$ , and  $\sigma$ .<sup>44</sup> The  $\mu$  receptor has 2 subtypes,  $\mu_1$  and  $\mu_2$ , with the former responsible for supraspinal analgesia and development of dependence and the latter responsible for many of the adverse effects of opioids, including respiratory depression, slowing of gastrointestinal (GI) motility, nausea, vomiting, and pruritus. The  $\mu_2$  receptor also produces sedation. The  $\kappa$  receptor is responsible for spinal analgesia and also contributes to opioid-induced sedation.<sup>45</sup> However, unlike the  $\mu$  receptor, there tends to be less respiratory depression at the  $\kappa$  receptor. The  $\kappa$  and  $\delta$  receptors have been subtyped as well, although specific differentiation of physiological effects from these subtypes has not been fully determined. Most opioid agents used for procedural sedation are primarily agonists at the  $\mu$  receptor. Other agents, such as nalbuphine and butorphanol, are primarily  $\kappa$  agonists while possessing antagonistic effects at the  $\mu$  receptor. These agents have seen little use in procedural sedation.

## Specific Medications

Commonly used opioids for procedural sedation include morphine and fentanyl. The role of these agents is demonstrated by their inclusion for years in many premixed regimens for procedural sedation. Although no longer recommended given concerns of adverse effects and prolonged

duration, the classic DPT included a mixture of Demerol (meperidine) with Phenergan (promethazine) and Thorazine (chlorpromazine).<sup>46</sup> Given that opioids provide predominantly analgesia, they are frequently combined with the benzodiazepine, midazolam. When such combinations are used, it should be expected that these agents will also have synergistic effects on respiratory function.<sup>47</sup>

When considering which opioid to use for procedural sedation, there are limited data to suggest an inherent advantage of one agent over another. Clinical differences to consider include their potency and duration of action (Table 6-2) as well as their time to peak effect. Given that most procedures are brief (<15–20 minutes), short-acting agents such as the synthetic opioid, fentanyl, have become popular for providing procedural sedation. However, proponents of using longer-acting agents such as morphine cite the advantage that prolonged analgesia (2–3 hours) can be provided following procedures that may result in prolonged pain, such as fracture reduction. Additionally, slight differences may exist in the sedative effect, as agents such as morphine are agonists at the  $\kappa$  (sedation) and  $\mu$  (analgesia) receptors, while synthetic agents such as fentanyl act predominantly at the  $\mu$  receptor, providing predominant analgesia and less sedation than morphine.

Morphine is a naturally occurring substance classified as a phenanthrene alkaloid that is found in opium, which is derived from the poppy plant (*Papaver somniferum*). Morphine has a half-life of approximately 2 to 3 hours and undergoes hepatic metabolism via glucuronidation, producing the metabolites morphine-6-glucuronide (M6G) and morphine-3-glucuronide (M3G), which are ultimately excreted by the kidneys. Morphine pharmacokinetics are significantly different in infants younger than 6 months, with a longer half-life due to immature hepatic function. Although M3G does not bind to opioid receptors, M6G is several times as potent as morphine. Given

**Table 6-2. Potency and Half-life of Opioids**

Opioid Agonists	Potency	Half-life
Morphine	1	2–3 h
Meperidine	0.1	2–3 h
Fentanyl	100	20–30 min
Sufentanil	1,000	20–30 min
Alfentanil	20	10–15 min
Remifentanil	100	5–8 min



its water solubility, M6G has limited penetration through the blood-brain barrier and is therefore of little clinical significance except in patients with renal insufficiency who receive repeated doses or a continuous infusion. Morphine dosing regimens for procedural sedation include slow titration in increments of 0.01 to 0.03 mg/kg up to 0.2 mg/kg. In most cases, the total dose ranges from 0.05 to 0.1 mg/kg. Given that it is less lipophilic than fentanyl, time to peak effect will be longer (5–10 minutes) than fentanyl.

In addition to their analgesic effects, morphine and opioids may lead to respiratory depression. By its actions on the brain stem, morphine decreases ventilatory response to elevated carbon dioxide, leading to hypoventilation. Morphine is commonly associated with GI effects as well, secondary to its action in the brain stem (area postrema), which may result in nausea and vomiting. Morphine's actions on the sympathetic nervous system can lead to vasodilatation and hypotension. Histamine release, stimulated by morphine, can exacerbate hypotension as well as cause flushing, pruritus, rash, and bronchospasm. Clinically significant effects on the cardiovascular system are generally rare except in patients with hypovolemia or comorbid cardiac conditions.

Given their lipophilic nature and short duration of action, synthetic opioids have gained popularity for use during procedural sedation. Fentanyl is a synthetic opioid acting primarily on the  $\mu$  receptor that is approximately 80 to 100 times more potent than morphine. It is commercially available in a solution containing 50  $\mu\text{g}/\text{mL}$ . Given the potency of the solution and doses commonly used for procedural sedation, titration with a tuberculin syringe or dilution to a 5- or 10- $\mu\text{g}/\text{mL}$  solution may be needed for procedural sedation. Initial IV dosing starts at 0.5 to 1  $\mu\text{g}/\text{kg}$ , which is then titrated to effect. In common clinical practice, fentanyl is combined with a sedative agent (midazolam or propofol) for brief painful procedures such as bone marrow aspirate or lumbar puncture.

Although generally administered intravenously, the intranasal route for fentanyl administration has been used in various clinical scenarios, most commonly when sedation or analgesia is required in a patient who does not have IV access. With the vast venous plexus in nasal passages and the lipophilic nature of fentanyl, the medication is quickly absorbed into the bloodstream. Intranasal administration results in a bioavailability of approximately 90%, onset time of 5 minutes, and duration of action of 1 hour.<sup>48</sup> With a pH of 6.4 and no preservatives, there is no direct irritation and pain from intranasal

administration. Options for intranasal administration include dripping the solution into the nose from a tuberculin syringe or use of an atomizing device to provide a fine, nonirritating mist. Applications in several clinical scenarios in the emergency department have demonstrated potential utility of intranasal fentanyl to treat acute and procedure-related pain.<sup>49–51</sup> For long bone fracture reduction, intranasal dosing at 1.7 µg/kg has been shown to be as effective as IV morphine at a dose of 0.1 mg/kg.<sup>49</sup> The intranasal route can also be considered to provide analgesia during placement of an IV cannula or even potentially combined with nitrous oxide, thereby allowing effective analgesia without obtaining IV access.

The side effect profile of fentanyl is similar to other µ receptor agonists with a few exceptions. Unlike morphine, there is no significant histamine release associated with fentanyl and its hemodynamic effects include primarily a decrease in systemic vascular resistance without a decrease in preload from vasodilatation. When considering its effects on respiratory function, the respiratory depression of fentanyl and all other opioids is directly and linearly related to their potency. Two additional issues relevant to synthetic opioids are potential effects on ICP and risks of chest wall rigidity. Anecdotal reports suggested the potential for synthetic opioids to increase ICP and decrease cerebral perfusion pressure (CPP) in adults with altered intracranial compliance. Subsequent work demonstrated that the mechanism responsible for the ICP increase was reflex cerebral vasodilation in response to the decrease in CPP.<sup>52</sup>

A second adverse effect specific to synthetic opioids is chest wall and laryngeal rigidity.<sup>53</sup> Clinical effects range from coughing following administration to true chest wall rigidity and impairment of ventilation resulting in hypoxemia. Although chest wall rigidity is generally described with doses in excess of 10 µg/kg or rapid administration, it can also occur with the doses used for procedural sedation. The effect is postulated to be mediated in part by the modulation of gamma-aminobutyric acid pathways at the spinal cord and basal ganglia through fentanyl binding to µ<sub>1</sub> and κ receptors. Incidence can be decreased by premedication with α<sub>2</sub>-adrenergic agonists, reversed with naloxone, and interrupted with neuromuscular blocking agents. Although rare, its occurrence should be considered if respiratory dysfunction is noted following use of synthetic opioids. Immediate treatment is necessary to prevent profound hypoxemia and cardiac arrest. Prevention is best

accomplished by slow administration of fentanyl (rates not to exceed 0.5 µg/kg/min over 1 µg/kg over 2 minutes).

Unlike the other opioids, which undergo hepatic metabolism, remifentanyl is metabolized by nonspecific esterases in the plasma. It is an ultrashort-acting opioid that has a clinical half-life of 5 to 10 minutes and a brief duration of effect even following prolonged infusions. These pharmacokinetic parameters hold true even in the neonatal population, making remifentanyl the only opioid whose pharmacokinetics are not altered by gestational or chronological age.<sup>54</sup> Its brief duration of action necessitates the use of a continuous infusion except for the briefest of procedures. Given its analgesic properties, remifentanyl has been combined with midazolam, propofol, and even dexmedetomidine as a means of providing analgesia during painful, invasive procedures.<sup>55,56</sup> Despite its efficacy, many of the clinical reports demonstrate a high incidence of respiratory depression and apnea, which may limit its applicability in procedural sedation.<sup>57</sup> However, given the ability of opioids to blunt the cough reflex, remifentanyl may have a role during airway procedures such as bronchoscopy.

## Summary

There are several medications that may be used in some combination for procedural sedation. One of the primary decision points remains whether the procedure requires only sedation or sedation and analgesia. For inherently painful procedures, a medication with analgesic effects is generally chosen as part of the regimen. The basis of this decision is an attempt to blunt painful input and avoid the need for general anesthetic doses of a sedative agent (propofol) and thereby limit its dose-related adverse effect profile. More importantly, it may not be feasible to provide effective sedation for painful procedures with medications that solely provide sedation (ie, midazolam and dexmedetomidine). As always, these agents should be combined with others, such as topical and local anesthetic agents, to limit their doses. When considering agents with analgesic properties, there are generally 3 that have been used in procedural sedation, including ketamine, nitrous oxide, and opioids. As outlined in this chapter, their applications will vary based on clinical scenario, available equipment, patient status, and experience of the health care professional providing sedation.

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CHAPTER 7

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## Complications of Procedural Sedation

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### Introduction



There is a growing demand for safe and effective pediatric procedural sedation performed outside the operating room in countries throughout the world.<sup>1</sup> Despite the growth in pediatric procedural sedation, no consensus definitions of sedation-related adverse events have been established. Most of the published studies that have evaluated and quantified adverse events in different pediatric settings are single-center, observational trials that lack the power to investigate the rare but most concerning adverse events such as aspiration and respiratory or cardiopulmonary arrest, which can occur in patients sedated outside the operating room. Heterogeneity in practice style, provision of sedation by various pediatric subspecialists (eg, emergency medicine, critical care, anesthesia, hospitalists), lack of uniform adverse event surveillance, and lack of a priori definitions of adverse events makes benchmarking difficult. Furthermore, some of the events that are described as adverse (ie, the need for the insertion of an oral airway) might actually be considered part of standard processes by some sedation practitioners. Serious adverse events are so infrequent, it would necessitate studying several thousand procedural sedations to assess incidence and demonstrate safety. Furthermore, once issues are addressed, a similar problem would be faced when attempting to identifying the efficacy of any intervention. Further issues arise as it is difficult to know how generalizable most sedation studies are to each given institution.



## Newer Definitions of Adverse Events

Despite the lack of standardization of adverse event definitions among studies that report on pediatric sedation, in some notable publications, authors have made an effort to have a consistent approach to defining adverse events based on the response of sedation practitioners to the event. In a retrospective review, Wheeler et al reported the use of propofol for procedural sedation in the pediatric intensive care unit for 110 medical procedures performed in 91 children over an 18-month study period.<sup>2</sup> Complications arising from propofol use were identified and defined. Respiratory complications were defined as the need for ventilator assistance due to airway obstruction, apnea, a decrease in oxygen saturation of more than 5% from baseline despite the administration of supplemental oxygen, or the use of jaw thrust or airway positioning maneuvers. Hypotension was defined as a reduction in blood pressure (BP) deviating significantly from baseline or decreasing to less than the fifth percentile for height and age, which was associated with signs and symptoms of decreased perfusion, such as prolonged capillary refill, decreased peripheral pulses, or unexplained tachycardia. Additional complications, such as cardiac arrhythmias, delayed recovery requiring overnight hospitalization, myoclonus or other seizure-like activity, vomiting, or failure to achieve adequate sedation, were also identified. Of the 91 children undergoing procedural sedation, 3 had brief episodes of oxygen desaturation to 91% to 92% while receiving supplemental oxygen. None of the children had airway obstruction, apnea, or bradypnea requiring bag-valve-mask positive pressure or mechanical ventilation. No child required placement of an endotracheal tube for any respiratory complications. Two of the 3 children with hypotension needed a 10-mL/kg bolus infusion of normal saline. No cardiac arrhythmias or adverse neurologic effects were identified. The authors concluded that pediatric intensive care physicians could safely and effectively administer propofol for diagnostic and therapeutic procedures.

Bhatt et al reported a collaborative effort to develop terminology for adverse events during sedation in the emergency department setting.<sup>3</sup> Experts from emergency medicine and anesthesiology participated. These investigators chose to include actions taken during a given event to help define the event. For instance, rather than define a specific pulse oximeter reading as oxygen desaturation, the authors chose to include any degree of desaturation that

was associated with a specific action designed to reverse that desaturation. They suggested that by employing these operational definitions, they would be less likely to miss a significant event that required intervention but never led to a very low oxygen saturation reading. Likewise, if studies use this compound definition, minor oxygen desaturation events that resolve in a short period without intervention would not be included as adverse events. Their contention was that such events probably do not belong in that category. In short, by combining the observation of the patient state (eg, hypoxemia, apnea) with actions taken by the sedation practitioner, the authors sought to identify and include dangerous events that would not be noted by some authors. Similarly, they attempted to exclude minor adverse events that require no intervention and therefore are of dubious importance.

## General Classification of Sedation Complications

### Major and Minor Adverse Events

#### *Major Adverse Events*

The previous descriptions of adverse events may go beyond what most sedation systems are capable of managing and recording due to complexity of the analysis. A more practical classification may be the broad differentiation between minor and major adverse events. Major adverse events include those which significantly change the life of the patient, even if only temporarily. These events would include death, hypoxia that results in brain injury, requirement for cardiopulmonary resuscitation, aspiration, or any event that results in hospitalization or increased level of care due to a sedation event. Adverse events such as these are unequivocally negative and deserve a full evaluation of circumstances whenever they occur. Most institutions require a sentinel event review or a root cause analysis to evaluate events for practitioner- or system-related errors. Fortunately, these events tend to be rare, occurring only once in several thousand sedation encounters. As such, they are difficult, if not impossible, to track in most clinical quality improvement settings or in the sedation studies that are usually published.

The most notable articles about major pediatric sedation adverse events were published in 2000 from Coté et al.<sup>4,5</sup> In these reports, the authors reviewed 95 incidents of death or critical injury to children who had undergone sedation. They examined data from a number of national databases that contained reports of major sedation complications collected over 10 years. Analysis of these cases by the multiple expert authors led to several conclusions, including the fact that most major adverse events were the result of specific deviations from care, such as inadequate monitoring, lack of effective rescue, or deficient backup systems. In addition, the authors were able to outline high-risk settings for pediatric sedation, such as the nonhospital setting, as well as the fact that combinations of 3 or more medications led to major serious complications much more often than single drug strategies. Unfortunately, given the methodology of the study, there was no way to extrapolate the incidence of these events or an accurate idea of how well these reports reflect the total number and nature of sedation complications.

### *Minor Adverse Events*

Minor adverse events include primarily airway and respiratory outcomes such as oxygen desaturation, failed sedation, airway obstruction, apnea, need for bag-valve-mask ventilation, or laryngospasm episodes that resolve and do not lead to a lasting effect on the patient. Other studies have also included hemodynamic alterations such as bradycardia and hypotension. Most hospitals and many published sedation studies track these events and count them as markers of safety or quality of care. It should be noted that the relationship between these minor events and major adverse events is uncertain. There are numerous studies that catalog such events. One example is the study by Bassett and colleagues evaluating the use of propofol for elective sedation in the emergency department.<sup>6</sup> The authors prospectively followed 393 patients through their sedation encounters. They reported 19 (5%) as having hypoxemia, 11 (3%) requiring airway manipulation (eg, jaw thrust), and 3 (0.8%) as requiring bag-valve-mask ventilation. There were no major adverse events. Trends in the frequency of these minor events, as reported in this study, can be used to mark the nature of sedation care, but they cannot be used to directly measure safety of a sedation system because these outcomes are not in themselves associated with injury. Furthermore, their frequency has not been shown to directly relate to major adverse events.

## Large Database Research

The Internet has provided a tool for collecting data simultaneously from numerous institutions from any imaginable geographic distribution. Data-sharing collaboratives have the power to collect huge numbers of cases that can begin to describe the incidence of relatively rare events. In 2004, a group of pediatric sedation researchers formed the Pediatric Sedation Research Consortium (PSRC). This group was specifically created to share data and create a database that would reach the kind of critical numbers that would allow a more accurate description of the incidence of relatively rare events. The methodology used involves prospective data collection on a Web-based tool that allows central storage of de-identified data that is compliant with Health Insurance Portability and Accountability Act rules. The 37 member institutions use data as part of their quality improvement processes, and aggregate data are used to evaluate adverse events and effectiveness related to sedation regimens.

The first publication from this group appeared in 2006 and involved an evaluation of the data from the first 30,000 sedation encounters in the database.<sup>7</sup> These encounters were collected from more than 30 institutions and included a variety of sedation practitioners using a number of sedation regimens. Predictably, major adverse events were rare, with no deaths and only one “code” in this data set (Table 7-1). On the other hand, there were 310 major unplanned airway interventions for an incidence of approximately 1 per 100 sedations. The authors considered these data in 2 lights. On the one hand, it was clear that serious adverse events were rare in this cohort, and it can be concluded that sedation provided by the sedation service teams involved in the study is relatively safe. On the other hand, this group of institutions represents a highly motivated group of sedation services that may outperform the standard sedation provision system. As such, these safety data may not be applicable to other institutions. The investigators also pointed out that the relatively frequent need to intervene and manage airway issues further emphasizes the need for appropriate training and preparation to keep sedated patients safe.

Another study from the PSRC was published in 2009, evaluating the adverse events and efficacy of sedation with propofol as delivered by the multi-specialty group of practitioners participating in the consortium.<sup>8</sup> Nearly 50,000 sedation encounters using propofol were evaluated. The results were remarkable for a low rate of serious adverse events (no deaths, 2 codes, and

**Table 7-1. Complications Reported in Pediatric Sedation Research Consortium Sedation Study**

<b>Adverse Events</b>	<b>Incidence per 10,000</b>	<b>N</b>	<b>95% CI</b>
Death	0	0	(0-0)
Cardiac arrest	0.3	1	(0-1.9)
Aspiration	0.3	1	(0-1.9)
Hypothermia	1.3	4	(0.4-3.4)
Seizure (unanticipated) during sedation	2.7	8	(1.1-5.2)
Stridor	4.3	11	(1.8-6.6)
Laryngospasm	4.3	13	(2.3-7.4)
Wheeze (new onset during sedation)	4.7	14	(2.5-7.8)
Allergic reaction (rash)	5.7	17	(3.3-9.1)
Intravenous-related problem or complication	11.0	33	(7.6-15.4)
Prolonged sedation	13.6	41	(9.8-18.5)
Prolonged recovery	22.3	67	(17.3-28.3)
Apnea (unexpected)	24.3	73	(19.1-30.5)
Secretions (requiring suction)	41.6	125	(34.7-49.6)
Vomiting during procedure (non-GI)	47.2	142	(39.8-55.7)
Desaturation—saturation <90%	156.5	470	(142.7-171.2)
Total adverse events	339.6 (1 per 29)	1,020	(308.1-371.5)
<b>Unplanned Treatments</b>	<b>Incidence per 10,000</b>	<b>N</b>	<b>95% CI</b>
Reversal agent required—unanticipated	1.7	5	(0.6-3.9)
Emergency anesthesia consult for airway	2.0	6	(0.7-4.3)
Admission to hospital—unanticipated	7.0	21	(4.3-10.7)
Intubation required—unanticipated	9.7	29	(6.5-13.9)
Airway (oral, unexpected requirement)	27.6	83	(22.0-34.2)
Bag-mask ventilation (unanticipated)	63.9	192	(55.2-73.6)
Total unplanned treatments	111.9 (1 per 89)	336	(85.3-130.2)
<b>Conditions Present During Procedure</b>	<b>Incidence per 10,000</b>	<b>N</b>	<b>95% CI</b>
Inadequate sedation, could not complete	88.9 (1 per 338)	267	(78.6-100.2)

Abbreviation: GI, gastrointestinal.

Reprinted from: Cravero JP, Blike GT, Beach M, et al. Incidence and nature of adverse events during pediatric sedation/anesthesia for procedures outside the operating room: report from the Pediatric Sedation Research Consortium. *Pediatrics*. 2006;118(3):1094.

6 aspiration events). An extremely high efficacy rate with a success rate of more than 99% was also documented. As with the prior study, the authors gathered information on airway interventions and found that 1 in 65 of the sedation encounters required an airway intervention such as a chin lift, jaw thrust, airway insertion, or positive pressure ventilation. Once again, the authors suggest that their data do not prove that propofol sedation is generally safe. Rather, they propose that, as practiced by the members of the consortium (with good protocols and appropriate oversight), excellent efficacy and a good safety record are possible. In another large study from PSRC published in 2011, Couloures et al compared pediatric sedation-practitioner medical specialty (ie, emergency medicine, intensive care physician, and anesthesiologist) in 135,751 pediatric procedural sedation events.<sup>9</sup> The authors found that pediatric procedural sedation outside the operating room was unlikely to yield major adverse outcomes. Furthermore, no differences were evident in adjusted or unadjusted rates of *major* complications among different pediatric subspecialists.

Limitations of such data analysis are clear. There is variability of, for example, technique, practitioners, and patient selection. Additionally, many of these studies come from centers with a long history of and significant experience with procedural sedation, thereby making it difficult to apply their data to smaller, less experienced centers. This makes direct comparison of sedation performances impossible. Consistency of reporting in any large group such as this is never as tight as that from one institution with a limited number of investigators. However, the authors point out that this type of data collection may give practitioners a general description of the events associated with this practice. They further suggest that interventions required during these sedation encounters could serve as a basis for evidence-driven training of sedation practitioners.

## Risk Factors for Adverse Events

Aside from the specific events themselves, several investigators have attempted to identify patients who may have a higher risk of such events. Vespasiano et al identified upper respiratory illness, prematurity, and chronic lung disease as predictors of an increased incidence of respiratory events and need for airway interventions when they reviewed 7,304 propofol sedation

events.<sup>10</sup> Several other studies have confirmed that airway or pulmonary issues, even in a patient with a currently stable respiratory state, and a history of prematurity should be considered when sedation risk is stratified.<sup>11,12</sup>

Studies from the anesthesia literature have demonstrated several potential risk factors for adverse perioperative events, most notably the presence of an upper respiratory infection (URI) with severe symptoms (eg, mucopurulent secretions, productive cough, temperature >38°C, lethargy, signs of pulmonary involvement).<sup>13,14</sup> It is suggested that these findings result in the postponement of elective surgery for a minimum of 4 weeks. The presence of prematurity, a history of reactive airway disease, parental smoking, and surgery involving the airway increased the risk of complications in patients with URIs.<sup>15,16</sup> In a more recent study of pediatric patients receiving sedation with propofol, Grunwell et al found that the presence of a URI, a history of obstructive sleep apnea or snoring, American Society of Anesthesiologists class 3, and older age were associated with increased probability of failed sedation (defined as inability to complete imaging or procedure due to a sedation-related complication).<sup>17</sup> These findings are consistent with Srinivasan et al, who evaluated predictors of adverse events in children receiving sedation with propofol.<sup>18</sup> Patients older than 12 years had a 4-fold increased risk for respiratory events and a 5-fold increased risk for the need for airway intervention. These investigators also reported that adjuvant use of glycopyrrolate or premedication with midazolam appeared to be most closely associated with the need for airway interventions.

Green et al employed a meta-analysis methodology of 8,282 pediatric ketamine sedations from 32 emergency medicine studies.<sup>19</sup> They reported that risk factors that predicted airway and respiratory adverse events included high intravenous (IV) doses of propofol (initial dose >2.5 mg/kg or total dose >5 mg/kg), administration to children younger than 2 years or older than 13 years, and coadministration of anticholinergic agents or benzodiazepines. Adverse events associated with IV dexmedetomidine have also been reported. In most instances, incidence and severity have been noted to vary with various dosing (low and high) protocols.<sup>20,21</sup> Mason et al reported that sedation with IV dexmedetomidine as the sole agent was associated with modest fluctuations in heart rate and BP independent of age, required no pharmacologic interventions, and did not result in any major adverse events.<sup>22</sup> Based on these findings, they advise that dexmedetomidine should be avoided in those patients who may not tolerate such fluctuations in heart

rate and BP. Furthermore, it has been shown the use of anticholinergic agents to treat dexmedetomidine-induced bradycardia may result in an exaggerated hypertensive response and likely should be avoided.<sup>23</sup> Based on these studies, it is generally recommended that dexmedetomidine be avoided in patients with preexisting bradyarrhythmias or atrioventricular block and those who are receiving negative chronotropic medications.<sup>24</sup> Likewise, the use of dexmedetomidine in patients receiving digoxin is contraindicated, as it has been associated with bradycardia and cardiac arrest in that group of patients.<sup>25</sup>

## Specific Clinical Scenarios: Treatment Options

As noted from the preceding discussion, airway and respiratory events comprise the majority of adverse events during procedural sedation and remain the primary indication for clinical intervention. The sedation practitioner generally determines the need for intervention based on clinical changes noted from direct observation of the patient (eg, paradoxical chest wall and abdominal movement) or from changes in monitoring parameters (eg, desaturation on pulse oximetry, loss of waveform or hypercapnia from the end-tidal carbon dioxide [ETCO<sub>2</sub>] monitor). See Chapter 4 for a full discussion of these monitoring modalities. Effective treatment requires not only the identification of hypoxemia but a rapid evaluation of the possible differential diagnosis to arrive at an effective treatment algorithm. During procedural sedation, most hypoxemia events relate to airway obstruction, hypoventilation, or apnea. Other, less likely etiologies include laryngospasm, bronchospasm, chest wall rigidity, and acid aspiration.

In general, when considering the differential diagnosis of hypoxemia, there are 5 etiologies to consider, including

1. A low inspired concentration of oxygen
2. Upper airway obstruction, apnea, or hypoventilation
3. Ventilation-perfusion inequalities
4. True shunt related to congenital cardiac disease
5. Diffusion abnormalities



Although a low inspired oxygen concentration is frequently not considered in the differential diagnosis of hypoxemia, it should be considered during procedural sedation if nitrous oxide is administered. Inspired oxygen concentration should be monitored to alert the practitioner in the event that a machine malfunction resulting in the delivery of a hypoxic gas mixture is the etiology of the patient's hypoxemia.

## The Respiratory System

### *Upper Airway Obstruction and Hypoventilation*

During procedural sedation, there may be significant overlap in the most common causes of hypoxemia, with some component of hypoventilation, apnea, and upper airway obstruction. Less common causes, including bronchospasm or acid aspiration, can generally be identified by auscultation of breath sounds. With administration of sedative agents, pharyngeal muscle tone is decreased, with relaxation of the genioglossus muscle leading to posterior movement of the tongue and the potential for obstruction of the oropharynx. Anatomic features predisposing infants and children to airway obstruction include a relatively large tongue in comparison with a small mouth and a large head, which can lead to neck flexion and further compromise of the airway. These anatomic features are compounded by physiological features, including a greater loss of functional residual capacity with sedative and analgesic medications coupled with a high oxygen consumption rate, which may result in rapid oxygen desaturation during periods of airway compromise. Upper airway obstruction may be further magnified in children with cognitive impairment and poor upper airway control in the awake state as well as the presence of adenotonsillar hypertrophy and baseline symptoms of obstructive sleep apnea. Many of these events follow initiation of sedation during bolus administration of sedative agents. These generally respond to repositioning of the airway with a triple airway maneuver (ie, jaw thrust, chin lift, head tilt). In more severe cases, placement of an oral or nasopharyngeal airway may be necessary. Given the depth of sedation, placement of a nasal airway may be preferred, as it is less likely to stimulate the gag reflex and precipitate coughing, vomiting, or laryngospasm. If these maneuvers fail to resolve the upper airway obstruction, application of continuous positive airway pressure (CPAP) with an anesthesia mask may be required. Decreasing the depth of sedation as feasible may also facilitate resolution or limit the recurrence of such problems.

### *Laryngospasm*

Partial or complete closure of the vocal cords is termed *laryngospasm*. Due to various development and anatomic reasons, laryngospasm occurs more commonly in the pediatric-aged patient. It should be viewed as primarily a primitive protective reflex in that stimulation of the airway with fluid or secretions results in glottal closure, thereby preventing aspiration. During procedural sedation, precipitating factors of laryngospasm include a light plane of sedation and some sort of upper airway irritation from secretions or stimulation of the airway by an artificial airway (oral airway) or a procedure (eg, bronchoscopy). Predisposing factors include a recent URI or exposure to passive tobacco smoke.<sup>13,14</sup> Changes in the degree of airway irritability may remain for up to 4 to 6 weeks after a URI and make these children more susceptible than normal to episodes of laryngospasm and bronchospasm.<sup>26,27</sup> Signs and symptoms mimic those of upper airway obstruction related to other causes, including diminished or absent airway change with paradoxical abdominal movement. Partial obstruction may allow some air exchange, resulting in a characteristic crowing noise. Interventions include airway maneuvers to maintain a clear airway and application of CPAP. Attempts to provide intermittent positive pressure ventilation with a face mask in this scenario often distends the stomach rather than the lungs, thereby impairing subsequent ventilation. It may be appropriate to deepen the level of sedation (generally with a bolus dose of propofol of 0.5–10 mg/kg), which tends to relax the vocal cords and relieve laryngospasm. While not scientifically studied, it has been suggested that pressure at the laryngospasm notch (anterior to the mastoid process behind the tragus) may break laryngospasm. It was originally described by C. Philip Larson, MD, and hence bears the name the Larson maneuver. It has been suggested that it be applied with the airway maneuvers of chin lift and jaw thrust during initial treatment of laryngospasm. Severe episodes of laryngospasm may result in total airway obstruction with profound hypoxemia followed by bradycardia unless treated immediately. If these measures fail to quickly reestablish gas exchange, further intervention is necessary with the administration of a neuromuscular blocking agent (succinylcholine if there are no contraindications). Prolonged attempts at non-pharmacologic management may result in hypoxemia, leading to bradycardia and asystole. In the rare case in which IV access is not present or is lost, provided that there are no contraindications to its use, succinylcholine (4–5 mg/kg) should be administered intramuscularly. In many scenarios, atropine is coadministered intramuscularly along with

succinylcholine to treat impending bradycardia. However, the risk of bradycardia precipitated by succinylcholine appears to be less with intramuscular (IM) when compared with IV administration; therefore, the use of atropine is not always necessary.<sup>28</sup> When administered into the deltoid rather than the quadriceps muscle, the onset time of succinylcholine is more rapid. Other have suggested the submental or intralingual injection to facilitate the onset given the high vascularity of the tongue. Uptake following IM administration is facilitated when succinylcholine is given early in the course of laryngospasm prior to onset of bradycardia and decreased cardiac output. When profound bradycardia has occurred and administration of succinylcholine and vasoactive medications is needed, the intraosseous (IO) route should be considered.<sup>29</sup> Early IO placement may be indicated when succinylcholine is contraindicated and there is profound laryngospasm that fails to respond to airway maneuvers. Regardless of the agent chosen, IM administration of non-depolarizing neuromuscular blocking agents is not effective in treatment of laryngospasm.<sup>30</sup> If laryngospasm occurs when IV access is present, succinylcholine and atropine may be administered intravenously, provided that there are no contraindications to succinylcholine. In this scenario, small doses of succinylcholine (0.1–0.2 mg/kg) are generally effective while providing only a brief period of neuromuscular blockade.

### *Bronchospasm*

Although the exact reasons remain undefined, the incidence of asthma and airway hyperreactivity are increasing in the pediatric-aged patient. As such, an increasing percentage of patients presenting for procedural sedation will give a history of asthma or some other type of airway reactivity. Risk factors for bronchospasm during anesthesia care and sedation include a recent history of a URI, passive or active exposure to tobacco smoke, recent aggravation of asthma symptoms, or a recent increase in medications to control asthma. Treatment of these problems begins with prevention by pre-sedation identification of patients at risk and administration of prophylactic therapy. Avoidance of elective sedation within 4 to 6 weeks of an acute URI is suggested; however, strict adherence to such a practice may be difficult, especially during the winter months, when the child may develop several closely spaced respiratory infections. Pre-sedation administration of corticosteroids, starting at least 48 hours prior to the event, may reduce the incidence of intraoperative problems. An inhaled  $\beta$ -adrenergic agonist in combination with an anticholinergic agent prior to sedation may lessen

intraoperative airway reactivity. This may be performed at home by the parents prior to arrival at the hospital or in the pre-sedation area. Many of the commonly chosen agents for sedation, including propofol, dexmedetomidine, and ketamine, have been shown to have beneficial effects on airway reactivity and are appropriate choices in such patients. If bronchospasm occurs surrounding the sedation event, standard therapies should be instituted, including the inhalation delivery of  $\beta$ -adrenergic agonists.

### *Aspiration of Gastric Contents*

In the perioperative setting, risk factors for perioperative aspiration in infants and children have been proposed, including patients presenting for emergency surgery, younger children compared with adolescents, bowel obstruction, inadequate perioperative fasting, and emergency surgery.<sup>31,32</sup> However, the literature addressing such risks in the sedation arena remain controversial, with some data suggesting a limited risk even in the absence of standard nil per os (NPO) times. Despite this, should apnea with the need for positive pressure ventilation or total loss of protective airway reflexes occur during procedural sedation, there may be a clinically significant risk of aspiration. These concerns lead the authors to recommend the use of standard NPO times as is clinically feasible. In the perioperative arena, evidence-based medicine is lacking to demonstrate the efficacy of prophylactic therapies aimed at decreasing gastric volume with use of motility agents such as metoclopramide, or increasing its pH with the use of agents that inhibit gastric acid production ( $H_2$ -antagonists or proton pump inhibitors). Based on the clinical scenario, anesthesia consultation for rapid sequence endotracheal intubation and airway protection may be the optimal choice in some patients.

Presentation of pulmonary aspiration may be obvious, with vomiting followed by coughing, laryngospasm, and hypoxemia, or more insidious, with unexplained hypoxemia or bronchospasm during anesthesia and in the post-sedation period. If aspiration is suspected, a chest radiograph should be obtained to assess the degree of parenchymal involvement. Following acid aspiration, therapy remains supportive with the administration of supplemental oxygen, positive end-expiratory pressure, and mechanical ventilation. Bronchodilators may be needed to treat bronchospasm. Antibiotics are indicated only for secondary bacterial infections, while corticosteroids have no role in the therapy of acid aspiration. Rigid bronchoscopy may be required to perform adequate bronchial toilet, especially if particulate matter is aspirated or to clear a collapsed lobe.

### *Chest Wall Rigidity*

Since their development, it has been known that synthetic opioids, including fentanyl, can cause skeletal muscle rigidity.<sup>33</sup> Such involvement may include respiratory musculature, laryngeal structures, or chest wall, with clinical manifestations ranging from mild coughing to severe chest wall and laryngeal rigidity, which impairs ventilation.<sup>34</sup> Skeletal muscle rigidity is thought to be mediated in part by the central modulation of gamma-aminobutyric acid pathways at the spinal cord and basal ganglia levels via fentanyl binding to  $\mu_1$  and  $\kappa$  opioid receptors. Although it is frequently assumed that chest wall rigidity only occurs with rapid administration of large doses, it has also been reported with the doses commonly used for procedural sedation (0.5–2  $\mu\text{g}/\text{kg}$ ). To prevent such problems, even small sedating doses of fentanyl should be administered slowly. Chest wall rigidity can be treated with naloxone; however, in extreme circumstances, neuromuscular blockade and airway management may be needed to rapidly reverse the respiratory compromise, which can rapidly result in hypoxemia, bradycardia, or even asystole.

## **The Cardiovascular System**

Although far less frequent than respiratory events, hemodynamic changes can be seen during procedural sedation. In most instances, these include hypotension or bradycardia. In the absence of comorbid conditions, these events have a low incidence and limited effect on physiological function and rarely require therapy. Alterations in BP may be induced not only by actual changes but also by artifact from the use of inappropriate equipment. This is particularly true in the pediatric patient, in whom the size and placement of the BP cuff are important. A cuff width that is two-thirds of the distance from the acromion process to the olecranon should be used. The diameter of the bladder of the cuff should be 20% greater than that of the extremity. Blood pressure will be erroneously elevated with a cuff that is too small and erroneously low if it is too large. In the rare circumstances when an intra-arterial cannula is in place, the level of the transducer, zeroing, and use of appropriate tubing to avoid damping of the tracing are necessary to obtain an accurate BP value.

As noted from many of the studies that have been reviewed, a BP decrease of 20% to 30% from baseline may normally occur following initiation of sedation. Several factors may affect the magnitude of the BP decrease,

including the agent chosen, dose, rapidity with which the bolus is administered, as well as the patient's underlying cardiac function and intravascular volume status. Although ongoing oral intake with clear liquids is encouraged up to 2 hours prior to the procedure, patients are frequently NPO for longer periods, thereby affecting the hemodynamic response to sedation. In rare cases, it may be advisable to provide an isotonic fluid bolus (20 mL/kg) prior to the initiation of sedation to mitigate the hemodynamic effects of sedative agents. In most circumstances, there are no consequences to the BP decrease and little to no effect on end-organ perfusion.

The cardiovascular effects of propofol and barbiturates include peripheral vasodilation and negative inotropic properties. On a cellular level, these agents inhibit calcium movement across cell membranes and from the sarcoplasmic reticulum, thereby depressing myocardial contractility. These effects are dose dependent and can be accentuated following rapid bolus administration, by coadministration of other agents such as benzodiazepines or opioids, and by the patient's comorbid conditions. The adverse hemodynamic profile of propofol administration can be prevented by the administration of calcium chloride.<sup>35</sup> In patients with comorbid cardiovascular disease and those who may not tolerate vasodilatation and a decrease in systemic vascular resistance, alternative agents may be used for procedural sedation. Ketamine generally increases heart rate and BP and provides bronchodilation due to the release of endogenous catecholamines.<sup>36</sup> Although the indirect sympathomimetic effects from endogenous catecholamine release generally overshadow ketamine's direct negative inotropic properties, acting to maintain BP and heart rate, hypotension and even cardiovascular collapse may occur in patients with diminished myocardial contractility, as ketamine's direct negative inotropic properties may predominate when endogenous catecholamine stores have been depleted by stress or chronic illness.<sup>37,38</sup>

Hypotension and bradycardia remain 2 of the most commonly reported adverse effects with dexmedetomidine. Bradycardia is more common and of a greater magnitude when dexmedetomidine is administered with other medications that possess negative chronotropic effects (eg, propofol, succinylcholine, digoxin, pyridostigmine), in scenarios when the negative chronotropic effects of a drug may be exaggerated (hypothermia or during vagotonic procedures, eg, laryngoscopy), and following large or rapid bolus doses.<sup>39,40</sup> As noted previously, treatment is rarely required for bradycardia and should be instituted cautiously, as hypertension has been reported in

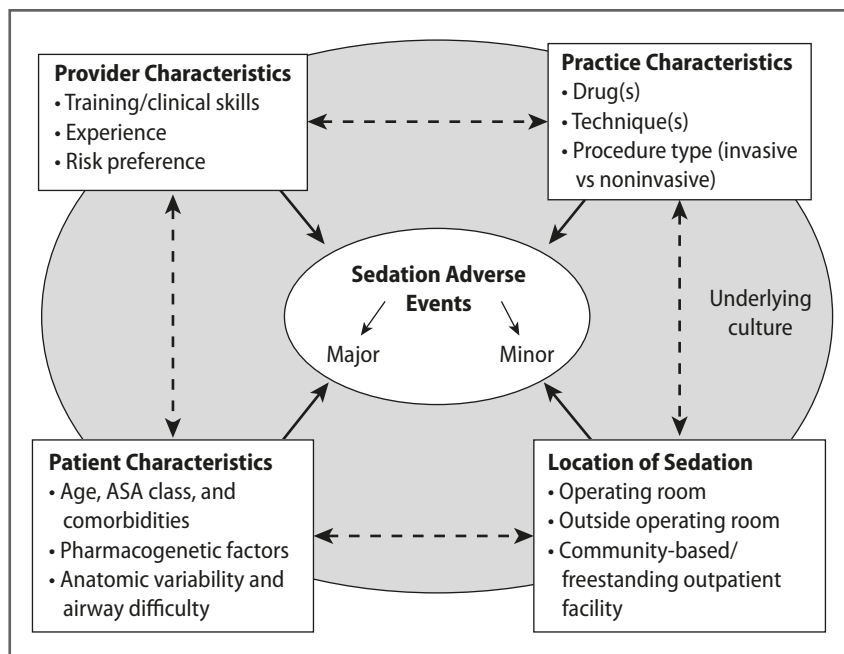
response to administration of an anticholinergic agent. Changes in BP or mean arterial pressure have been noted to follow a biphasic effect, with an initial increase in systolic BP (sBP) and reflex decrease in heart rate followed by a stabilization of sBP and heart rate at a value below the baseline. Stimulation of peripheral postsynaptic  $\alpha_{2B}$ -adrenergic receptors results in vasoconstriction and the initial increase in BP followed by a decrease in BP related to central presynaptic  $\alpha_{2A}$ -adrenergic receptor stimulated sympathectomy. Although generally well tolerated, caution is required when using this agent in patients who may not tolerate its negative chronotropic and dromotropic effects.<sup>41,42</sup> Alternatively, it may be feasible to mitigate these effects by the coadministration of ketamine and dexmedetomidine.<sup>43</sup>

## Summary

Taken together, data from the PSRC and smaller reports that have been published in the sedation literature make a few facts clear. Most adverse events involve airway compromise, apnea, or hypopnea with the development of hypoxemia. Without a doubt, this entails the greatest risk to the patient receiving procedural sedation. In light of all of the evidence that has been produced concerning adverse events in sedation (including the PSRC data outlined previously), there appears to be a clear set of critical competencies that can be formulated. Given these concerns, the authors and editors would recommend

1. Practitioners should be able to recognize and treat an obstructed airway or apnea. Monitoring strategies for accomplishing this may include direct observation, ETCO<sub>2</sub> monitoring, impedance plethysmography, a precordial stethoscope, or pulse oximetry. In particular, ETCO<sub>2</sub> monitoring has been shown to be a significant “lead” monitor in the area of ventilation monitoring. Its use is clearly associated with earlier detection of apnea when compared with pulse oximeter monitoring alone.
2. Sedation practitioners should be trained in managing airway obstruction or central apnea once it is detected, including the ability to open a blocked airway and provide positive pressure ventilation. This would include training in the selection and placement of oral airways, nasal airways, a laryngeal mask airway, and appropriate bag-valve-mask ventilation techniques.

3. Of equal importance to the safe delivery of sedation is the *setting* of sedation (Figure 7-1). Each sedation event occurs in a context that includes tools, personnel, and an evaluation of patient pathology. It is suggested that the sedation system be set up to provide adequate backup systems and rescue capability to allow the rare major adverse event to be managed in a way that avoids permanent injury to the patient. This would include the availability of all the equipment required to provide resuscitation and life support for a child as well as staff who have advanced airway and resuscitation skills. There is abundant evidence in the pediatric sedation literature that lack of appropriate sedation rescue capability is a key component of serious adverse outcomes in sedation.<sup>5,44</sup> In addition, there is evidence that the skill of the practitioner can affect the effectiveness of resuscitation when a major problem occurs during procedural sedation.<sup>45</sup>
4. The safety profile of procedural sedation outside the operating room is different from general anesthesia or deep sedation provided by the anesthesiologist in the operating room setting. Based on their education and

**Figure 7-1**

Factors influencing safe procedural sedation. Abbreviation: ASA, American Society of Anesthesiologists.



training, anesthesiologists already have knowledge of sedatives, analgesics, and anesthetic agents and possess the advanced intervention skills necessary to rescue patients from respiratory or hemodynamic compromise within the confines of well-equipped operating rooms with ready availability of highly trained staff for assistance. Pediatric subspecialists who work as sedation practitioners outside the operating room should not consider it a sign of weakness to consult or refer to anesthesiology colleagues in specific cases (Table 7-2).

With such caveats in mind, we can get closer to our ultimate goal of safe and effective procedural sedation. The process of avoiding complications or lessening their potential effect on patients begins with determining the most common adverse events. Through large databases, high-risk groups and contributing factors to these adverse events can be identified. In so doing, we may able to prevent many of these events. Alternatively, with appropriate monitoring, early interventions may prevent progression of the event. As a final safety measure, it is suggested that appropriate training and resources be in place so that the sedation practitioner is able to rescue the patient when these events occur.

**Table 7-2. Sedation Patients Who May Benefit From Anesthesiology Consultation or Referral**

Condition	Comment
<ul style="list-style-type: none"><li>• ASA class 3–5</li><li>• Past requirement for general anesthesia for procedure</li></ul>	
<ul style="list-style-type: none"><li>• Morbidly obese (BMI ≥35)</li></ul>	
<ul style="list-style-type: none"><li>• Patients with craniofacial anomalies, mucopolysaccharidoses, and other congenital syndromes with difficult airway</li></ul>	
<ul style="list-style-type: none"><li>• Anterior mediastinal mass, cystic hygroma, or other masses with potential for airway compression</li><li>• Symptomatic vascular ring (stridor or respiratory compromise)</li></ul>	If short, non-painful procedure (eg, CT imaging), may attempt without sedation.
<ul style="list-style-type: none"><li>• Myocardial dysfunction, uncorrected complex congenital heart defects (including single ventricle and shunt dependent lesions), arrhythmias</li><li>• Intracardiac masses</li><li>• Pulmonary hypertension</li></ul>	Consultation with cardiologist or cardiac anesthesia may be warranted.

**Table 7-2. Sedation Patients Who May Benefit From Anesthesiology Consultation or Referral, continued**

Condition	Comment
<ul style="list-style-type: none"> <li>• Oxygen requirement</li> <li>• Malacia of the larynx, trachea, or bronchi with need for possible positive pressure ventilation</li> <li>• Active asthma with wheezing</li> <li>• Obstructive sleep apnea documented by sleep study or suspected from history</li> </ul>	Consultation with pulmonologist may be helpful to screen patient.
<ul style="list-style-type: none"> <li>• Prematurity with post-conceptual age &lt;60 wk</li> <li>• Patient with chronic lung disease</li> <li>• Neuromuscular disease affecting pharyngeal tone</li> <li>• Poor control of airway secretions</li> </ul>	Premature newborns are sensitive to opioids and at risk for apnea or desaturation. Consultation with neurologist or pulmonologist may be helpful to screen patient.
<ul style="list-style-type: none"> <li>• Mental status changes</li> <li>• Uncontrolled or poorly controlled seizure disorder</li> <li>• Hydrocephalus or increased intracranial pressure</li> </ul>	Consultation with neurosurgeon or neurologist may be helpful to screen patient. Patient may need airway protection, depending on mental status.
<ul style="list-style-type: none"> <li>• GERD</li> </ul>	Consultation with gastrointestinal physician may be helpful.  Delaying of sedation if not urgent until GERD better controlled with medical therapy

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; CT, computed tomography; GERD, gastroesophageal reflux disease.

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## CHAPTER 8

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# Specific Clinical Scenarios

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## Introduction



Most of this manual has focused on the approach to sedation from the standpoint of the routine encompassing the relatively healthy patient, use of familiar medications, familiar locations, and a non-emergent procedure. Although the basics of sedation, including patient evaluation, preparation, choice of medication, monitoring, and recovery, should be consistent, there are variations that may occur when the sedation practitioner is called to unfamiliar locations or presented with novel clinical scenarios in patients with comorbid conditions. In these scenarios, as the severity of illness increases and the routine is broken, the chances for morbidity and mortality may increase. Furthermore, the urgency of these procedures is another significant factor that may escalate the potential for adverse outcomes. These scenarios mandate that we stick to basic principles of safe sedation with the ability to practice out of our comfort zone to provide the best arena for completion of the intended procedure while limiting the incidence of morbidity.

## Clinical Scenarios



### Emergent Sedation

Emergent sedation describes the urgent or emergent nature to provide sedation to a patient for a diagnostic or therapeutic procedure, regardless of the length of fasting state. The literature would suggest that most children

receiving emergent sedation may not have fasted for any significant period.<sup>1</sup> The American College of Emergency Physicians (ACEP) acknowledges the non-fasted state in its procedural sedation and analgesia (PSA) guidelines: “Recent food intake is not a contraindication for administering PSA, but should be considered in choosing the timing and target level of sedation.” The American Academy of Pediatrics (AAP) position on emergent sedation states: “The practitioner must always balance the possible risks of sedating non-fasted patients with the benefits and necessity for completing the procedure.”<sup>2</sup> However, with elective sedation, the AAP position is unequivocal: its recommendation is to use the fasting guidelines developed by the American Society of Anesthesiologists (ASA). These guidelines include a minimum nil per os (NPO) of 2 hours for clear liquids; 4 hours for human milk; 6 hours for infant formula, nonhuman milk, or a light meal; and up to 8 hours for a heavy meal.<sup>3</sup>

To date, evidence is lacking to demonstrate that non-fasted children undergoing emergent sedation are at a higher risk for pulmonary aspiration.<sup>4</sup> Agrawal et al, in a case series of 1,014 children undergoing emergent sedation, noted that 56% of these children did not meet the criteria for ASA fasting guidelines.<sup>5</sup> There was no incidence of pulmonary aspiration, despite 15 reported cases of vomiting. In another study that further highlighted the absence of severe adverse events, Roback et al demonstrated that in more than one-third of the 1,555 children receiving emergent sedation in a prospective database, there were no cases of pulmonary aspiration.<sup>6</sup> The children in this group had 4 hours or less of fasting. There was no difference in the incidence of reported complications, including vomiting, desaturation, apnea, and laryngospasm, between the fasted and non-fasted children. Despite these data, there is still insufficient evidence to definitely prove the safety of sedation in patients that have not been adequately fasted. In many cases, the depth of sedation is adjusted so that the minimal level of sedation is provided which allows successful completion of the procedure. In all cases, the risk to benefit ratio of the options for completion of the procedure (sedation versus general anesthesia with rapid sequence intubation [RSI] and airway control) should be considered.

Results of these studies provide compelling, albeit preliminary, data on the safety of emergent sedation even when NPO guidelines are not met. That being said, there can be a subset of patients who are at a high risk for aspiration during procedural sedation, such as those with altered mental

status.<sup>4,5</sup> In these circumstances, it may be prudent to perform endotracheal intubation and protect the airway. This is best accomplished by performing an endotracheal intubation with RSI. Because RSI is beyond the scope of this manual, please refer to pediatric anesthesiology or pediatric critical care texts for a full discussion.

For the most part, emergent sedation will be administered to children in the emergency department (ED) setting. Patients can present with the spectrum of injury or illness that may be associated with pain. The broader terminology, PSA, incorporates sedation and analgesia. Advancements made in PSA partly result from the need for a more robust group of practitioners providing sedation in the outpatient and inpatient areas.<sup>7</sup> The main goals of PSA should always be to minimize patient risk and maximize patient safety. There are additional goals of PSA that warrant consideration (Box 8-1). For the clinician to achieve these goals, a sedation management plan must be developed and tailored to the individual child's needs. The sedation management plan for the child undergoing PSA consists of 5 phases that may be modified by the clinician as necessary (Box 8-2).

The first phase of the plan involves preparation for the case, and it is important for the clinician to ensure adequate time for the performance of PSA. This may be challenging, particularly in a busy ED setting. At least one other staff member, most likely an ED nurse, must be available to participate on the

#### **Box 8-1. Goals of Procedural Sedation and Analgesia**

Patient safety—minimize risk  
Patient comfort—minimize patient movement  
Patient cooperation—minimize recovery time  
Amnesia—maximize efficiency

#### **Box 8-2. Sedation Management Plan**

- 1. Preparation** (resources)
- 2. Patient assessment** (focused history and physical examination)
- 3. Informed consent<sup>a</sup>—Assent<sup>b</sup>—Time-out<sup>c</sup>**
- 4. Procedural sedation and analgesia** (pharmacologic and non-pharmacologic techniques)
- 5. Recovery and discharge**

<sup>a</sup> Written or verbal consent. Institution dependent.

<sup>b</sup> May be appropriate for children older than 6 years.<sup>8</sup>

<sup>c</sup> Requirement of The Joint Commission.



care team of the patient during PSA.<sup>9</sup> It must also be remembered that the person performing the procedure should not be the same person directing the sedation. Basic resources required (age- and size-appropriate equipment) during the administration of sedatives and analgesics must be readily available and checked for proper working performance. These basic resources can include, but are not limited to, monitors of vital signs. Continuous pulse oximetry remains a standard of care for procedural sedation. Continuous capnography is rapidly being considered an additional standard of care for monitoring. It can provide an early warning of the presence of hypoventilation or airway obstruction. Additional basic resources are oxygen, suction, emergency medications, intravenous (IV) fluids, and equipment for resuscitation and advanced airway management.

The second phase of the plan is patient assessment, and this should begin with a focused history that obtains information about the child's presenting complaint. A mnemonic that is quite useful for obtaining a focused history is SAMPLE: signs and symptoms, *a*llergies, *m*edications, *p*ast medical problems, *l*ast food or liquid, and *e*vents leading to the injury or illness.<sup>10</sup>

The physical examination should be considered an integral part of patient assessment. Crucial to this physical examination is a focused airway assessment; please refer to Chapter 2 for a full discussion of airway assessment. The Mallampati scoring system is useful for assessing the airway.<sup>11</sup> This airway classification is based on the visibility of various intraoral structures and is classified as

- Class 1: Soft palate, fauces, uvula, and tonsillar pillars are visible.
- Class 2: Soft palate, fauces, and uvula are visible.
- Class 3: Soft palate and base of uvula are visible.
- Class 4: Soft palate is not visible.

The Mallampati scoring system has been validated in the adult population and shown to be predictive of difficult airway management, including bag-valve-mask ventilation and endotracheal intubation. Based on patient assessment and presence of comorbid conditions, the ASA physical status classification is assigned (Table 8-1). Although this physical status classification was developed to predict risk for adverse events during general anesthesia, it can be a useful tool in determining sedation risks as well. Another measure of patient assessment has been suggested by the PSA fasting clinical

**Table 8-1. American Society of Anesthesiologists  
Physical Status Classification System**

ASA Class <sup>a</sup>	Description
1	No underlying medical problems
2	Mild systemic illness (well-controlled asthma, corrected CHD)
3	Severe systemic illness (sickle cell disease, severe asthma, uncorrected CHD)
4	Severe systemic illness that is a constant threat to life (uncorrected cyanotic CHD)
5	Patient is unlikely to survive 24 hours with or without the procedure.
6	Declared brain-dead patient

Abbreviations: ASA, American Society of Anesthesiologists; CHD, congenital heart disease.

<sup>a</sup>An E is added for an emergency procedure.

Adapted from: ASA Physical Status Classification System of the American Society of Anesthesiologists, by permission of ASA. A copy of the full text can be obtained from ASA, 1061 American Lane, Schaumburg, Illinois 60173.

practice advisory committee of emergency physicians (Figure 8-1).<sup>12</sup> The basis for this assessment is to evaluate aspiration risk in the presence of patient acuity, urgency, timing, and type of ingested substance. This assessment tool is particularly useful in the ED setting for emergent and urgent procedures in which standard NPO guidelines may not be fulfilled.

Obtaining informed consent comprises the third phase of the sedation management plan. It is the responsibility of the clinician who is administering sedation to the child to obtain consent from the parent or guardian. If the decision-making capacity and the child are age appropriate, the clinician should seek their assent.<sup>8</sup> Also, when it is appropriate, the child can be involved in the process of informed consent or assent. Some examples of issues to discuss when obtaining informed consent are the plans, benefits, and risks associated with the sedation. In the non-fasted patient, a discussion of potential risks, including aspiration and the need for mechanical ventilation, are appropriate. An additional process that must occur before the initiation of PSA is the time-out, which is a requirement of The Joint Commission and part of the standard universal protocol. It is the responsibility of the sedation team to verify the procedure to be performed and site, confirm patient identity (using 2 forms of identification, eg, name and medical record number) and consent, and arrange an introduction by each team member and his or her role during the procedure.

Figure 8-1

Standard-risk patient <sup>a</sup>				
Oral intake in the prior 3 hours	Procedural Urgency <sup>b</sup>			
	Emergent Procedure	Urgent Procedure	Semi-Urgent	Non-Urgent
Nothing	All levels of sedation	All levels of sedation	All levels of sedation	All levels of sedation
Clear liquids only	All levels of sedation	All levels of sedation	Up to and including brief deep sedation	Up to and including extended moderate sedation
Light snack	All levels of sedation	Up to and including brief deep sedation	Up to and including dissociative sedation; non-extended moderate sedation	Minimal sedation only
Heavier snack or meal	All levels of sedation	Up to and including extended moderate sedation	Minimal sedation only	Minimal sedation only

Higher-risk patient <sup>a</sup>				
Oral intake in the prior 3 hours	Procedural Urgency <sup>b</sup>			
	Emergent Procedure	Urgent Procedure	Semi-Urgent	Non-Urgent
Nothing	All levels of sedation	All levels of sedation	All levels of sedation	All levels of sedation
Clear liquids only	All levels of sedation	Up to and including brief deep sedation	Up to and including extended moderate sedation	Minimal sedation only
Light snack	All levels of sedation	Up to and including dissociative sedation; non-extended moderate sedation	Minimal sedation only	Minimal sedation only
Heavier snack or meal	All levels of sedation	Up to and including dissociative sedation; non-extended moderate sedation	Minimal sedation only	Minimal sedation only

Procedural sedation and analgesia targeted depth and duration<sup>c</sup>

↓ Increasing potential aspiration risk ↓

Minimal sedation only

Dissociative sedation; brief or intermediate-length moderate sedation

Extended moderate sedation

Brief deep sedation

Intermediate or extended-length deep sedation

Brief: <10 minutes

Intermediate: 10-20 minutes

Extended: >20 minutes

## Fasting clinical practice advisory

<sup>a</sup> Higher-risk patients are those with one or more of the following present to a degree individually or cumulatively judged clinically important by the treating physician:

- Potential for difficult or prolonged assisted ventilation should an airway complication occur (eg, short neck, small mandible/micrognathia, large tongue, tracheomalacia, laryngomalacia, history of difficult intubation, congenital anomalies of the airway and neck, sleep apnea)
- Conditions predisposing to esophageal reflux (eg, elevated intracranial pressure, esophageal, hiatal hernia, peptic ulcer disease, gastritis, bowel obstruction, ileus, tracheo-esophageal fistula)
- Extremes of age (eg, >70 years or <6 months)
- Severe systemic disease with definite functional limitation (ie, ASA physical status 3 or greater)
- Other clinical findings leading the EP to judge the patient to be at higher than standard risk (eg, altered level of consciousness, frail appearance)

<sup>b</sup> Procedural urgency:

- Emergent (eg, cardioversion for life-threatening dysrhythmia, reduction of markedly angulated fracture or dislocation with soft tissue or vascular compromise, intractable pain or suffering).
- Urgent (eg, care of dirty wounds and lacerations, animal and human bites, abscess incision and drainage, fracture reduction, hip reduction, lumbar puncture for suspected meningitis, arthrocentesis, neuroimaging for trauma)
- Semi-urgent (eg, care of clean wounds and lacerations, shoulder reduction, neuroimaging for new-onset seizure, foreign body removal, sexual assault examination)
- Non-urgent or elective (eg, non-vegetable foreign body in external auditory canal, chronic embedded soft tissue foreign body, ingrown toenail)

**Figure 8-1, continued**

<sup>c</sup> Procedural sedation and analgesia terminology and definitions:

- Minimal sedation (anxiolysis): A drug-induced state during which patients respond normally to verbal commands. Although cognitive function and coordination may be impaired, ventilatory and cardiovascular functions are unaffected.
- Moderate sedation (formerly “conscious sedation”): A drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation. Reflex withdrawal from a painful stimulus is not considered a purposeful response. No interventions are required to maintain a patent airway, and spontaneous ventilation is adequate. Cardiovascular function is usually maintained.
- Dissociative sedation: A trance-like cataleptic state induced by the dissociative agent ketamine characterized by profound analgesia and amnesia, with retention of protective airway reflexes, spontaneous respirations, and cardiopulmonary stability.
- Deep sedation: A drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully following repeated or painful stimulation. The ability to independently maintain ventilatory function may be impaired. Patients may require assistance in maintaining a patent airway and spontaneous ventilation may be inadequate. Cardiovascular function is usually maintained.
- General anesthesia: A drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation. The ability to independently maintain ventilatory function is often impaired. Patients often require assistance in maintaining a patent airway, and positive pressure ventilation may be required because of depressed spontaneous ventilation or drug-induced depression of neuromuscular function. Cardiovascular function may be impaired.

Reprinted from: Green SM, Roback MG, Miner JR, Burton JH, Krauss B. Fasting and emergency department procedural sedation and analgesia: a consensus-based clinical practice advisory. *Ann Emerg Med.* 2007;49(4):454–461, by permission of Elsevier.

The administration of PSA is the fourth phase of the sedation management plan. Sedative and analgesic agents should be tailored to meet the individual needs of the child, clinical scenario, and procedure. Examples of specific agents and suggested dosing regimens are outlined in Table 8-2. Adjunctive techniques such as hypnosis, distraction, and visual imagery should also be considered. As with all sedative and analgesic agents, these are merely approximate suggestions for the initiation of PSA. These agents should be titrated to effect as the physiological parameters allow. Reversal agents and dosing are outlined in Table 8-3.

The final phase of the sedation management plan consists of recovery and discharge of the child. It is important to be aware that the patient who has been administered PSA may remain at risk for developing complications during the recovery phase. Therefore, these patients should continue to be monitored during their recovery from single or combination pharmacologic agents. In addition, the recovery area should be equipped with

**Table 8-2. Commonly Used Sedative and Analgesic Agents**

Drug	Effect	Dose	Onset (min)	Duration (min)	Comments
Midazolam	Sedative-hypnotic, anxiolysis, amnesia	IV: 0.05–0.1 mg/kg (max dose 2 mg) IN: 0.2–0.5 mg/kg PO: 0.5–0.75 mg/kg	1–3 10–15 20–30	45–60 15–60 60–90	Possibly can have a paradoxical effect
Diazepam	Sedative-hypnotic, anxiolysis, amnesia	IV: 0.05–0.1 mg/kg PO: 0.2–0.5 mg/kg	4–5 15–30	60–120	IV route is irritating to vein.
Propofol	Sedative-hypnotic	IV: 0.5 mg/kg titrated to effect. Infusion: 50–200 $\mu$ g/kg/min	<1	10–15	Irritating to vein, hypotension, respiratory depression, avoid in soy/egg allergy.
Pentobarbital	Sedative-hypnotic	IV: 1–2 mg/kg titrated to effect, every 2–5 min (max 200 mg)	3–5	15–90	May be accompanied by restlessness or emergence agitation
Ketamine	Dissociative effect, sedative, analgesic	IV: 0.5–1.0 mg/kg titrated to effect IM: 4–6 mg/kg PO: 5–10 mg/kg	1–2 3–5 30	1–2 30–90 30–90	Hallucinations, salivation, vomiting
Etomidate	Sedative-hypnotic	0.1–0.2 mg/kg titrated to effect	<1	5–15	Irritating to vein, myoclonus, adrenal suppression
Dexmedetomidine	Sedative-hypnotic	Loading dose: 0.5–1 $\mu$ g/kg IV Infusion rate: 0.5–2 $\mu$ g/kg/h IN: 1–2 $\mu$ g/kg	5–10 10–30	30–90 30–60	Initial hypertension, followed by hypotension and bradycardia; avoid in conduction disturbances or bradycardia.

**Table 8-2. Commonly Used Sedative and Analgesic Agents, continued**

Drug	Effect	Dose	Onset (min)	Duration (min)	Comments
Fentanyl	Analgesia	IV: 0.5–1 $\mu$ g/kg titrated to effect	1–5	30–45	Synergistic effect with benzodiazepines; possible chest wall rigidity with rapid IV bolus
Morphine	Analgesia	IV: 0.05–0.15 mg/kg	5	60–120	Synergistic effect with benzodiazepines
Nitrous oxide	Inhalational agent, sedative, amnesia, mild analgesia	Inhaled: 30%–50%, mixed with oxygen	1–2	<5	Avoid with vitamin B <sub>12</sub> deficiency or hypoxemia.

Abbreviations: IM, intramuscular; IN, intranasal; IV, intravenous; PO, oral.

**Table 8-3. Reversal Agents for Procedural Sedation**

Drug	Effect	Dose	Onset (min)	Duration (min)	Comments
Flumazenil	Benzodiazepine reversal	IV: 0.01 mg/kg to a maximum of 1 mg	1–2	30–60	May develop seizures with severe hepatic impairment or when other medications have been administered or ingested, such as tricyclic antidepressants. Contraindicated in patients with an underlying seizure disorder. May require more than one dose to see effect.
Naloxone	Opioid reversal	IV: 0.1 mg/kg to a maximum of 2 mg	1–2	60–90	May require more than one dose to see effect. Effect may be shorter than opioid, so ongoing observation is required.

Abbreviation: IV, intravenous.

age-appropriate airway and resuscitation equipment. Discharge from the recovery area may occur once the criteria delineated by the institution are satisfied. Every patient should receive discharge instructions as well as a telephone number to call for concerns post-procedure.

## Magnetic Resonance Imaging Sedation

Magnetic resonance imaging (MRI) is a noninvasive diagnostic procedure that offers a distinct advantage over other imaging modalities by using nonionizing radiation. Magnetic resonance imaging offers superior soft-tissue contrast and can create 3-dimensional images through any plane of the body.<sup>13</sup> The success of an MRI study is directly related to the ability of a patient to lie motionless. The use of sedation for a pediatric patient undergoing MRI continues to markedly increase.<sup>14</sup> There are several factors that may account for this increase in volume. During the past 10 years, there have been significant technologic advances in diagnostic radiology as well as a dramatic change in the number of different practitioners involved in the role of sedation practitioners.<sup>15</sup> The outcome is a better study that creates a greater demand for their use. Despite these advances, some MRI studies can be quite lengthy. On the basis of the length of some of these MRI studies and the need for a motionless patient, it is not uncommon for children to require sedation.<sup>16</sup> There are a number of other reasons that affect the need for sedation during MRI, including claustrophobia and the noise generated by the study.

At most institutions, the responsibility for sedation in the MRI setting is managed by non-radiologists. A number of paradigms exist with regard to sedation for MRI. The sedation service paradigm in MRI can be run by a physician (eg, pediatric intensive care, anesthesiologists, pediatric hospitalists, ED physicians) or sedation nurse practitioner with oversight by a physician.<sup>15</sup> Given the presence of various specialty MRI sedation practitioners, it is imperative that all health care professionals involved in the process have a fundamental knowledge of the technologic and safety principles in this technology. Magnetic resonance imaging incorporates the use of static and gradient magnetic fields with radiofrequency pulses to produce precise images of the body. Magnetic field strengths for the MRI in clinical use range from 0.2 to 3.0 tesla (T).<sup>17</sup> The tesla is a measure of the strength of the magnetic field (1 T = 10,000 gauss). Quality of the image is related to the strength of the

magnetic field. There are a number of safety considerations associated with the MRI environment.<sup>17,18</sup> By most recent estimates, more than 200 million patients have had MRI examinations.<sup>17</sup> There are no reports of harmful physiological effects from magnetic fields. The greatest risks encountered is with ferromagnetic objects or equipment and their projectile effect in the MRI scanner room.<sup>19</sup> Additionally, dental hardware of any internal ferromagnetic material can potentially cause injury in a sedated child secondary to heating of the metal, leading to burns during progress of the scan.

The potential injury from such events cannot be overemphasized, as such mistakes have resulted in death or severe morbidity. Therefore, all involved must be aware of these risks, educated, and thoroughly screened to ensure that they do not have internal or external metallic devices that may pose a safety threat. Some hospitals have even resorted to using metal detectors at the entrance to their scanners as an additional safety feature. Despite these concerns, improvements in technology have resulted in the development of monitoring equipment, including end-tidal carbon dioxide monitoring and infusion devices, that are MRI compatible and can be used safely within the MRI room. These devices have markedly increased the feasibility and safety of sedation within this environment.

The sedation management plan for the child undergoing MRI is similar to that of any child undergoing procedural sedation as outlined in this handbook. Ultimately, the sedation plan must be tailored to meet the individual needs of the patient. Before a plan can be formulated, an evaluation with details of the past medical history, physical examination, and reason for the study will be required. Most of the time, the MRI scan will be performed as an elective procedure and the child should meet ASA recommendations for fasting.<sup>3</sup> The goals of sedation for MRI are similar to those in other clinical settings and are discussed in further detail in this chapter. No matter what the clinical setting is, the most important of these goals is to maximize patient safety and minimize patient risk. Additional goals for MRI sedation should include immobility, cooperation, amnesia, anxiolysis, and short recovery stay.

For the most part, providing sedation for MRI means that the practitioner will be away from the child's airway during the study. There is no way to avoid this situation given the logistics of the MRI scanner. It is important to recognize that the sedated pediatric patient may progress from the



intended level of sedation to a deeper level of sedation or even general anesthesia. Early recognition of cardiac or respiratory decompensation with early intervention is critical. That being said, the sedation practitioner must have experience with managing the pediatric airway in the event of respiratory depression, apnea, upper airway obstruction, or laryngospasm.

Choice of sedative-hypnotic agent(s) for MRI will depend on patient-related factors as well as duration of the study. There are several commonly used sedative-hypnotic agents for children receiving sedation in the MRI suite (Table 8-4). A number of studies have examined sedation regimens for pediatric patients undergoing MRI. A review of the medical literature on sedation agents in pediatrics reveals the once-common practice of using chloral hydrate. Although this drug was considered part of the sedation regimen for MRI and other diagnostic modalities, this is no longer the situation. In general, newer agents have replaced chloral hydrate. This process has been accelerated by the fact that several formulations of chloral hydrate have been discontinued.

Propofol is one of the commonly used sedation agents for children undergoing MRI.<sup>20,21</sup> Pershad et al conducted a prospective, randomized trial of pediatric patients administered propofol or a combination of midazolam, pentobarbital, and fentanyl.<sup>21</sup> This study demonstrated a significantly faster onset and recovery time associated with propofol. However, the use of propofol as the sole agent compared with the triple regimen of midazolam, pentobarbital, and fentanyl revealed similar results with regard to their overall efficacy.<sup>21</sup>

Dexmedetomidine has been successfully used during MRI studies. Mason et al<sup>22</sup> performed a retrospective review of the use of dexmedetomidine as a single agent for children undergoing MRI.<sup>22</sup> A high dose of dexmedetomidine (3 µg/kg bolus over 10 minutes followed by an infusion of 2 µg/kg/h) was successful for 97.6% of 747 children having MRI studies. The investigation revealed fluctuations in heart rate and blood pressure with a 16% incidence of bradycardia. The authors did note their concerns that dexmedetomidine was contraindicated for use in patients at risk for aspiration, vascular disease, and cardiac and respiratory compromise.

**Table 8-4. Commonly Used Agents for Magnetic Resonance Imaging Sedation**

Drug	Effect	Dose	Onset (min)	Duration (min)	Comments
Propofol	Sedative-hypnotic	IV: 0.5–1 mg/kg titrated to effect Infusion rate: 100–150 µg/kg/min	<1	10–15	Hypotension, respiratory depression, pain on administration, thrombophlebitis
Pentobarbital	Sedative-hypnotic	IV: initial bolus of 1–6 mg/kg titrated to effect; 1–2 mg/kg every 2–5 min (max 200 mg)	3–5	15–90	May be accompanied by restlessness and emergence delirium.
Dexmedetomidine	Sedative-hypnotic	Loading dose of 1–3 µg/kg over 10 min Infusion rate of 1–2 µg/kg/h	5–10	30–90	Initial hemodynamic response is hypertension, followed by bradycardia and hypotension. Avoid in heart block, renal failure, or severe hepatic impairment.
Midazolam	Sedative-hypnotic, anxiolysis, amnesia	PO: 0.5–0.75 mg/kg (max 20 mg) IN: 0.2–0.5 mg/kg IV: 0.05–0.1 mg/kg titrated to effect (max 2 mg per dose)	20–30 10–15 1–3	60–90 15–60 45–60	Possible paradoxical effect, good synergistic effect with opioids

Abbreviations: IN, intranasal; IV, intravenous; PO, oral.

## The Cardiac Catheterization Suite

The goal of sedation for cardiac catheterization of the pediatric patient is to provide anxiolysis, analgesia, amnesia, and immobility with minimal interference of hemodynamic parameters. Data collected should be as normal as possible, with minimal alteration by medications or ventilatory support.<sup>23</sup> Due to advancements in noninvasive diagnostic imaging, particularly via echocardiography and MRI, the need for cardiac catheterization for diagnosis and hemodynamic measurements is decreasing. However, interventional cardiac catheterization continues to increase, being used to treat a number of conditions, including patent ductus arteriosus, atrial septal defect, ventricular septal defect, collateral vessels, vessel or valvular stenosis, and conduction abnormalities.<sup>24</sup> Therapeutic transcatheter interventions frequently necessitate general anesthesia and airway protection to prevent accidental patient movement or ensure airway control during periods of hemodynamic instability. Patients undergoing radiofrequency ablation procedures may have longer procedure times than other cardiac catheterization patients. This longer procedure time may result in a deeper level of sedation or the need for general anesthesia to maintain immobility and ensure patient comfort.<sup>25</sup> Endotracheal intubation may also be required when various therapeutic maneuvers such as the administration of 100% oxygen or nitric oxide are planned as part of the catheterization procedure.

When planning the sedation or general anesthesia for a cardiac catheterization, the anesthesiologist should be aware of the underlying physiology, purpose of the procedure, and potential sedation-induced changes in hemodynamic parameters. Most importantly, the effect of hemodynamic changes on the physiology based on congenital heart disease must be understood and anticipated. In many institutions, simple procedures were formerly performed with sedation provided by the pediatric cardiologist. However, as catheterization procedures become prolonged and more complex and the complexity of the anatomy and physiology of the patients increased, the sedation needs have been transitioned to sedation and anesthesia practitioners.<sup>24</sup>

As with all off-site sedations, specific complexities may be added by the location. The cardiac catheterization suite is generally remote from operating rooms but should be equipped with monitoring, oxygen sources, suction devices, scavenging capability, and intubation and resuscitative equipment. Children may be placed on a forced air-warming blanket to avoid iatrogenic hypothermia because the catheterization room is often kept cold when

everyone is wearing heavy protective lead aprons. Blood pressure monitoring and pulse oximetry are placed commonly on the upper extremities, as the femoral area is accessed for the procedure. Given the presence of cardiac catheterization equipment and fluoroscopy, the airway may be distant from the sedation practitioner. Attention to and education on appropriate safety and shielding from ionizing radiation should be provided to sedation practitioners as well as badges to record the exposure magnitude.

When planning sedation for pediatric cardiac catheterization, the anesthesiologist or sedation practitioner should consider the goals of catheterization, presence of congenital heart disease, associated physiology, hemodynamic parameters, and possible comorbidities. Diagnostic catheterizations may be performed to obtain a biopsy specimen after cardiac transplant or to further clarify hemodynamic parameters. Diagnostic procedures may be shorter in duration and accomplished with the use of deep sedation and airway monitoring. Interventional procedures on young children often require endotracheal intubation and general anesthesia. For example, closure of an atrial or ventricular septal defect requires transesophageal echocardiography for device placement and, therefore, endotracheal intubation.<sup>23</sup> Radiofrequency ablation can require prolonged catheterization. In one study, general anesthesia and deep sedation were usually needed in patients 10 years or younger. However, the majority of patients older than 10 years required no sedation for the ablation.<sup>25</sup>

Congenital heart abnormalities and potential hemodynamic alterations by sedation require consideration. The effect of sedative agents on various hemodynamic parameters, including heart rate, systemic vascular resistance (SVR), pulmonary vascular resistance (PVR), preload, and contractility, should be considered. The effect of these factors varies significantly based on the anatomy and physiology of the congenital heart defect. Hypotension can exacerbate a right-to-left shunt and lead to further decreases in oxygen saturation, decreased cardiac output, and cardiac ischemia. Hypertension can increase afterload and regurgitant flow in the presence of valvular disease. Supplemental oxygen may increase pulmonary blood flow and result in pulmonary edema. Hypercapnia and a low pH can aggravate pulmonary hypertension. Hypovolemia can lead to poor cardiac output, whereas hypervolemia can provoke congestive heart failure. Possible repercussions of each sedative agent, as well as volume and oxygen use, should be carefully considered.

Sedation of the child with pulmonary arterial hypertension is particularly challenging. Several mechanisms of hemodynamic deterioration, including acute increases in PVR, changes in ventricular contractility and function, and coronary hypoperfusion, can contribute to morbidity and mortality. Patients with severe pulmonary hypertension are at risk of pulmonary hypertensive crises and cardiac arrest.<sup>26</sup> The goal of anesthetic management is to provide adequate anesthesia and analgesia while minimizing increases in PVR and depression of myocardial function. Efforts are made to avoid alveolar hypoventilation, hypoxemia, hypercapnia, metabolic acidosis, and activation of the sympathetic nervous system by noxious stimuli. Pulmonary vascular resistance will increase as the  $P_{aO_2}$  decreases below 60 mm Hg. When acidosis and hypoxia are present, the increase in PVR is dramatically greater. Respiratory and metabolic acidosis can cause an increase in PVR.<sup>27</sup> An acute increase in PVR can occur with tracheal suctioning and intubation.<sup>28</sup> As many anesthetic agents exhibit mixed hemodynamic effects and may be deleterious when used in full anesthetic dosages, a balanced sedative technique in which sub-anesthetic doses of several drugs are combined to provide general anesthesia can be used for patients with pulmonary hypertension. Given the effect of hypoxemia and hypercapnia on PVR, most of these patients require endotracheal intubation, controlled ventilation, and general anesthesia for procedures. Carmosino et al describe the use of oral or IV midazolam pre-sedation followed by induction with midazolam, fentanyl, and a small dose of propofol or low concentration of sevoflurane.<sup>29</sup> Anesthesia is then maintained with sevoflurane or isoflurane while IV anesthesia is maintained via propofol infusion or intermittent fentanyl.<sup>29</sup> Given the tenuous nature of patients with pulmonary hypertension, it is generally suggested that these patients be cared for by pediatric anesthesiologists with significant experience with congenital heart disease and only at institutions with capabilities for extracorporeal life support.

Several different sedatives and combinations of agents have been used to provide procedural sedation for children undergoing cardiac catheterization. Historically, a combination of meperidine, promethazine, and chlorpromazine was used. Medications still in use include benzodiazepines, opioids, ketamine, propofol, and dexmedetomidine.<sup>30</sup> It is important to recognize that hemodynamic alterations can occur when these medications are used at full sedating doses (Table 8-5). A mainstay of cardiac catheterization sedation is ketamine. This drug maintains cardiovascular stability by the release of

**Table 8-5. Hemodynamic Effects of Sedative Agents**

Medication	Dose	Potential Hemodynamic Effect	Effective Scenario	Hemodynamic Contraindication
Midazolam	0.1–0.2 mg/kg IV (max bolus dose 2 mg); 0.5–1 mg/kg PO (max 20 mg)	Minimal change	Pre-procedure anxiolysis	None
Ketamine	3–8 mg/kg IM; 1 mg/kg IV followed by an infusion at 50–70 µg/kg/min	Increased HR; increased BP; stable to increased SVR; variable effect on PVR	To maintain afterload and cardiac output	Lesions that cannot tolerate increased afterload (mitral and aortic regurgitation); controversial in severe fixed pulmonary hypertension
Propofol	1–2 mg/kg IV followed by an infusion at 100–150 µg/kg/min	Decreased afterload and SVR; decreased BP; stable PVR; suppression of ectopic atrial tachycardia	HTN Elevated SVR	Lesions were decreased; SVR is harmful (fixed pulmonary HTN or Eisenmenger syndrome). Radiofrequency ablation of ectopic atrial arrhythmia.
Dexmedetomidine	1 µg/kg IV followed by an infusion at 0.2–0.7 µg/kg/h	Decreased HR and BP. Decreased endogenous catecholamine release. Decreased sinus and AV node function. Limited effect on respiratory function.	Treatment of various atrial and ventricular tachyarrhythmias. Treatment or prevention of post-procedure tachyarrhythmias. Maintenance of spontaneous ventilation.	Scenarios where negative chronotropic effects are exaggerated (hypothermia or concomitant medications such as digoxin or β-adrenergic antagonists). Electrophysiologic studies. Underlying AV or sinus node dysfunction. Patients at risk for bradycardia with preexisting conduction disturbances.

Abbreviations: AV, atrioventricular; BP, blood pressure; HR, heart rate; HTN, hypertension; IM, intramuscular; IV, intravenous; PO, oral; PVR, pulmonary vascular resistance; SVR, systemic vascular resistance.

endogenous catecholamines, except in patients with severely depressed ventricular function, where it can lead to hemodynamic compromise. Ketamine provides effective analgesia and spontaneous ventilation can be maintained. It is generally combined with an anti-sialagogue, such as glycopyrrolate, to prevent hypersalivation and potential airway irritability.<sup>23</sup> There is some controversy as to the drug's effects on PVR and whether it can be used in patients with pulmonary hypertension.<sup>26,31</sup> Ketamine's systemic hemodynamic effects, with maintenance of blood pressure and SVR, offer potential benefits to patients with pulmonary hypertension. If used with a pulmonary vasodilator or enriched oxygen, ketamine can preserve coronary blood flow, limit right-to-left ventricular septal shift, and maintain the ratio of pulmonary to systemic blood flow.<sup>26</sup> The most recent literature supports its use even in patients with pulmonary hypertension.<sup>31</sup>

Propofol has been used for total IV anesthesia for cardiac catheterization. Advantages include a quick onset and recovery, the ability to titrate the depth of anesthesia easily, and an antiemetic effect. However, it can lead to a higher incidence of systemic hypotension when used alone at full anesthetic doses. For this reason, a combination of low-dose propofol (25 µg/kg/min) and low-dose ketamine (25 µg/kg/min) can be used, resulting in adequate sedation and stable hemodynamics. Propofol has been associated with metabolic acidosis, even in short-term use. Due to the risk of propofol infusion syndrome, characterized by metabolic acidosis, rhabdomyolysis, and death, it should not be used for prolonged sedation beyond the catheterization laboratory.<sup>24,30</sup> Of note, propofol may suppress ectopic atrial tachycardia and interfere with identification of the ectopic foci during a radiofrequency ablation procedure.<sup>23</sup>

Dexmedetomidine is an  $\alpha_2$ -adrenergic agonist with sedative, analgesic, and anxiolytic properties. It has limited effects on respiratory function when administered within clinical dosing guidelines. Dexmedetomidine also modulates the release of catecholamines from the sympathetic nervous system, which is ideal for cardiac catheterization procedures.<sup>30,32</sup> However, at normal doses, it provides insufficient sedation alone, especially for the painful aspects of the procedure, including cannula placement.<sup>23,33</sup> To overcome such issues, it has been used in combination with other sedative agents, such as ketamine, propofol, or midazolam.<sup>30,34</sup> Dexmedetomidine does have the potential to produce dose-dependent decreases in blood pressure and heart rate and may depress sinus and atrioventricular nodal function in pediatric

patients. Therefore, it may be associated with adverse effects in patients at risk for bradycardia and atrioventricular nodal block.<sup>35</sup>

Opioid-based sedation for cardiac catheterization has been associated with the need for controlled ventilation and a higher incidence of postoperative vomiting. Alfentanil and fentanyl have been studied for sedation during catheterization.<sup>36</sup> Both medications require careful airway monitoring. Premedication with an antiemetic should be considered. For complex procedures, general anesthesia and inhalation agents may be used. Sevoflurane has proven to be ideal for this purpose.<sup>37</sup> Local application of a topical anesthetic cream such as EMLA (eutectic mixture of lidocaine 2.5% and prilocaine 2.5%) at least 30 minutes before the procedure over both groins and any other access site can significantly reduce the amount of sedation required for insertion of catheters and the remainder of the usually painless procedure.<sup>23</sup>

## **The Former Preterm Infant**

Ongoing advancements in neonatal intensive care have led to a growing number of preterm infants surviving beyond the neonatal period. Many of these infants will require sedation for diagnostic studies or surgical repairs during the first few years of life. Preterm infants, defined as infants whose gestational age at birth is less than 37 weeks, are at higher risk of respiratory depression and apnea after sedation or anesthesia until the post-conceptual age (PCA) of 48 to 60 weeks.<sup>38</sup> These infants comprise a heterogeneous group, ranging from the healthy infant born at 36 weeks to the former extremely low birth weight infant with severe lung disease on home oxygen.<sup>39</sup> Of further concern is the extensive demonstration in animal models of neuronal cell death after neonatal exposure to various sedative and anesthetic agents.<sup>40</sup> How this laboratory information translates to pediatric medicine is unclear and must be balanced with the need to treat pain and safely sedate infants. Factors of prematurity, a wide range of chronic illness, and risks of medications must be considered carefully when creating a sedation plan for the former preterm infant.

A predominant physical ailment that places the former preterm infant at risk with sedation is bronchopulmonary dysplasia (BPD). The disease has changed pathologically and clinically with the use of antenatal steroids and postnatal surfactant and is referred to as the “new BPD.” The current BPD afflicting preterm infants is not the injury or repair paradigm of traditional BPD but a maldevelopment sequence resulting from interference or



interruption of normal signaling for terminal maturation of alveolarization of the lungs.<sup>41,42</sup> Children with the former pathologic model of BPD may exhibit chronic oxygen dependency for the first 2 years of life. For traditional and new BPD, approximately 50% of infants require readmission to the hospital for respiratory distress. Many suffer with chronic cough or wheeze, particularly during viral infections such as respiratory syncytial virus.<sup>43</sup> In the first 2 years of life, children with BPD have high airway resistance, evidence of gas trapping, and ventilation inhomogeneity. In most children, lung growth and remodeling result in progressive improvement of pulmonary function. However, airway obstruction, hyperreactivity, and hyperinflation have been demonstrated in adolescents who had BPD.<sup>44</sup> The future pulmonary status of the former preterm infant with “new BPD” has yet to be determined.<sup>45</sup>

Bronchopulmonary dysplasia, very low birth weight, and the associated prolonged stay in the neonatal intensive care unit (NICU) can affect many organ systems, including the heart, lungs, central nervous system, gastrointestinal tract, and kidneys.<sup>46</sup> Table 8-6 lists a number of potential medical issues of the former preterm infant. Many of these may affect the decision to sedate, as well as the choice of sedative. For example, a former preterm infant with poor feeding and failure to thrive will be at greater risk of respiratory depression following sedation and may require respiratory support. In such patients, the decision to use general anesthesia with endotracheal intubation or the use of a laryngeal mask airway may be preferable to procedural sedation. Hepatic or renal impairment can alter the metabolism and clearance of certain sedative agents, thereby prolonging sedation. Former preterm infants frequently exhibit limited potential for vascular access following months of venipuncture, peripheral intravascular catheters, and central venous lines.<sup>47</sup> This will impose limitations on sedation and may place the patient at greater risk, should vascular access be required emergently for resuscitation. After a prolonged course of endotracheal intubation and mechanical ventilation, infants may develop glottal and subglottic abnormalities, rendering sedation challenging in the face of a tenuous airway. These factors may also increase the risk of morbidity should endotracheal intubation and general anesthesia be chosen. All of these factors must be considered when faced with the prospect of sedating the former premature infant. These should be considered when evaluating the risk to benefit ratio of any procedure.

**Table 8-6. Potential Medical Issues of the Former Preterm Infant**

<b>Organ Systems</b>	<b>Considerations</b>
Respiratory and airway systems	<ul style="list-style-type: none"> <li>• Bacterial and viral pneumonia</li> <li>• Viral bronchiolitis</li> <li>• Reactive airway disease</li> <li>• Glottic and subglottic damage</li> <li>• Tracheal and bronchial stenosis or malacia</li> <li>• Acute life-threatening events</li> <li>• Chronic lung disease and bronchopulmonary dysplasia</li> </ul>
Cardiovascular system	<ul style="list-style-type: none"> <li>• Systemic hypertension</li> <li>• Pulmonary hypertension</li> <li>• Cor pulmonale</li> <li>• Limited availability of vascular access</li> </ul>
Neurologic system	<ul style="list-style-type: none"> <li>• History of intraventricular hemorrhage</li> <li>• Hydrocephalus</li> <li>• Seizure disorder</li> <li>• Hypoxic encephalopathy</li> </ul>
Nutrition and gastrointestinal system	<ul style="list-style-type: none"> <li>• Failure to thrive</li> <li>• Feeding intolerance</li> <li>• Gastroesophageal reflux</li> <li>• Cholestasis related to parenteral nutrition</li> </ul>
Other	<ul style="list-style-type: none"> <li>• Decreased renal blood flow and glomerular filtration rate</li> <li>• Renal calcification</li> <li>• Osteopenia and rickets</li> <li>• Fractures</li> </ul>

Apnea and bradycardia of prematurity are common occurrences in the premature infant. They appear to be related to an immature respiratory musculature and central control mechanism, an unstable elastic rib cage, an upper airway that is prone to obstruction, and a lower airway that is prone to collapse.<sup>48</sup> These factors are aggravated by associated conditions, including hypothermia and anemia.<sup>48</sup> Once a former preterm infant is discharged from the NICU, the risk of recurrence for apnea or bradycardia, without sedation, depends on the gestational age of the infant and the postmenstrual age of the last apneic or bradycardiac event. An apneic episode is defined as a pause in breathing for 15 seconds when accompanied by bradycardia. A bradycardiac episode is defined as a heart rate below 80 beats per minute.<sup>49</sup> Although breathing irregularities and periodic breathing are seen during

sleep in healthy preterm infants, true apnea with or without bradycardia is pathologic. Anesthetic agents produce changes in the mechanics and central control of the respiratory center. Inhaled anesthetic agents decrease muscle tone in the airways, chest wall, and diaphragm and may further induce apnea by reducing response to ventilatory stimulants, including  $\text{PaCO}_2$  and  $\text{PaO}_2$  and resultant increased work of breathing. Intravenous sedative agents and opioids produce a dose-dependent depression of the medullary respiratory center, leading to a decreased responsiveness to  $\text{PaCO}_2$ .<sup>50</sup>

Numerous studies have evaluated the risk for postoperative apnea in the former preterm infant, with the goal of determining the optimal timing of surgery.<sup>51</sup> Analysis by Charles J. Coté, MD, pooled data from several studies, thereby giving it more statistical power than studies from any single institution. This analysis found that the incidence of postoperative apnea in the former preterm infant was strongly related to PCA as well as gestational age. Other important aspects of the risk analysis included apnea at home, history of chronic lung disease, central nervous system morbidity, and anemia. After controlling for gestational age and PCA, the only independent risk factor for postoperative apnea, especially in those patients older than 44 weeks' PCA, was anemia. In a study of former preterm infants, anemic infants had an 80% incidence of postoperative apnea versus 21% in infants with a normal hematocrit ( $P < 0.03$ ).<sup>50</sup> However, there is no evidence that transfusion of red blood cells will lower incidence of postoperative apnea.<sup>39</sup> The 1995 meta-analysis of 8 series on postoperative apnea in the preterm infant established a predictive curve that demonstrated an incidence of apnea of less than 1% at 54 weeks' PCA.<sup>51</sup> This model possessed an upper confidence interval of 60 weeks' PCA. Thus, the value of 60 weeks' PCA is the most conservative interpretation for a safety margin.<sup>52</sup> Many centers admit former preterm infants for postoperative monitoring for at least 8 to 12 hours if they are younger than 60 weeks' PCA. To date, despite new anesthetic agents and protocols, there is no study to lower this monitoring age threshold. The need to monitor is not dependent on the agent used. Several studies have noted post-sedation apnea following administration of chloral hydrate.<sup>53–55</sup> There are a number of factors to consider in identifying the risk of postoperative apnea in the former preterm infant (Box 8-3). Medical history and data can assist in identifying these factors (Table 8-7). As in patients of other age groups, there are several possible sedative options for the former preterm infant (Table 8-8). Use of any of these medications for sedation in the former

preterm infant should occur only after analysis of apnea risk factors. In a retrospective cohort study of 1,394 infants undergoing MRI examination with chloral hydrate sedation, post-procedural oxyhemoglobin desaturation in 262 preterm infants was directly correlated with younger chronologic, but not gestational, age. Preterm infants had more post-procedural bradycardia than term infants, while oxyhemoglobin desaturation was not seen in preterm infants older than 48 weeks' PCA.<sup>55</sup> Despite this, we believe that the conservative approach is to provide post-sedation monitoring of the preterm infant up to 60 weeks' PCA. Other factors associated with postoperative apnea further increase necessity of post-sedation monitoring (see Box 8-3).

#### **Box 8-3. Risk Factors for Postoperative Apnea**

Post-conceptual age <60 weeks

Apnea at home—history of home monitor use

History of chronic lung disease or use of oxygen at home

Central nervous system morbidity

Anemia: hemoglobin <10 g/dL

**Table 8-7. Pre-sedation Assessment of the Former Preterm Infant**

<b>Organ Systems</b>	<b>Considerations</b>
Respiratory system	<ul style="list-style-type: none"> <li>• Use of oxygen at home</li> <li>• Apnea monitor at home</li> <li>• Age of last known apnea</li> <li>• History of caffeine use</li> <li>• Use of diuretics, bronchodilators, or corticosteroids</li> <li>• Recent respiratory infections</li> <li>• History of endotracheal intubation and duration of mechanical ventilation</li> </ul>
Nutrition	<ul style="list-style-type: none"> <li>• History of poor weight gain</li> <li>• Method of feeding: oral, nasogastric tube, gastrostomy tube</li> </ul>
Neurologic	<ul style="list-style-type: none"> <li>• Seizure history</li> <li>• History of intraventricular hemorrhage</li> <li>• Failure to reach developmental milestones</li> <li>• Presence of hydrocephalus</li> </ul>
Hematologic	<ul style="list-style-type: none"> <li>• Anemia</li> </ul>
Other	<ul style="list-style-type: none"> <li>• Vascular access history—previous central venous lines</li> <li>• Sedation and anesthetic history</li> <li>• Multiple hospitalizations</li> <li>• ALTE history</li> </ul>

Abbreviation: ALTE, acute life-threatening event.

**Table 8-8. Sedation Options for the Former Preterm Infant**

Drug	Dose	Comments
Midazolam	0.05–0.15 mg/kg IV over 5 min	Associated with respiratory depression and arrest. May cause hypotension.
Lorazepam	0.05–0.1 mg/kg IV	Respiratory depression
Chloral hydrate	25–75 mg/kg/dose PO or PR	Apnea or bradycardia in the former preterm infant. Can accumulate with hepatic or renal disease. Displaces bilirubin from protein binding sites.
Pentobarbital	2–6 mg/kg IV slowly	Respiratory depression. Cardiovascular depression.
Dexmedetomidine	0.3–0.7 µg/kg/h	May cause hypotension or bradycardia. Has not been studied in premature infants. Tolerated in infants beyond the newborn period.
Fentanyl	0.5–4 µg/kg by slow IV push	Respiratory depression. Chest wall rigidity can occur.
Morphine	0.05–0.1 mg/kg per slow IV push	Respiratory depression, hypotension, bradycardia.

Abbreviations: IV, intravenous; PO, oral; PR, per rectum.

Neuraxial analgesia, including spinal anesthesia and epidural analgesia, are used to minimize potential exposure of the developing brain to general anesthetics and lessen the likelihood of postoperative respiratory complications, including postoperative apnea. Analysis of 4 trials comparing spinal and general anesthesia in former preterm infants undergoing inguinal herniorrhaphy found a reduction in the incidence of postoperative apnea only if systemic sedatives were avoided.<sup>56</sup> Postoperative monitoring is still recommended for former premature infants with ongoing apnea and complex medical histories.<sup>57</sup> Caffeine has been used to prevent apnea in preterm infants. A review concluded that caffeine was effective in decreasing the incidence of postoperative apnea in the former preterm infant, although the number of patients was small.<sup>58</sup> A dose of 10 mg/kg IV caffeine has been used to decrease the incidence of apnea, but further studies are needed.

## The Non-fasted Patient (Non-Nil Per Os Status)

The purpose of fasting prior to a procedure requiring sedation is to reduce the volume of gastric contents, decrease the risk of reflux of highly acidic gastric secretions, and ultimately reduce the risk of pulmonary aspiration. The

frequency of perioperative pulmonary aspiration in children has been determined to be low. However, Warner et al demonstrated that children undergoing emergency procedures had a greater frequency of pulmonary aspiration compared with children undergoing elective procedures.<sup>59</sup> Most of the patients who aspirated in the perioperative period had a bowel obstruction or ileus, suggesting factors other than fasting status affected risk of regurgitation of gastric contents.<sup>59</sup> Gastric content volumes for infants, children, and adolescents undergoing MRI studies under deep propofol sedation show considerable variation and no correlation with fasting times.<sup>60</sup> While the goal of preoperative fasting is sustained in current anesthesia practice, it is recognized that prolonged fasting can have a negative effect on physiological parameters, including intravascular volume status and blood glucose levels, and efficacy of various sedation regimens, as well as psychologic factors of patient behavior and parent satisfaction.<sup>61</sup> The ASA recommends that children undergoing sedation for scheduled elective procedures requiring general anesthesia, regional anesthesia, or sedation/analgesia (monitored anesthesia care) fast for 2 hours after receiving clear liquids; 4 hours after breastfeeding; 6 hours after ingesting a light meal, formula, or milk other than human milk; and 8 hours after ingesting a large or fatty meal.<sup>3</sup>

The importance of fasting to prevent aspiration during nonelective procedural sedation remains unclear. The volume of gastric contents in a trauma situation may be better linked to the interval between the last meal and the trauma rather than the length of fasting. Thus, the injured child may be considered a patient with a full stomach.<sup>60</sup> Guidelines from the ASA call for careful assessment of the target level of sedation, consideration of a delay in the procedure, and possible endotracheal intubation for airway protection.<sup>62</sup> The AAP recommends using the “lightest effective sedation” when timing of the fast is questionable.<sup>63,64</sup> Because many of the requirements for non-fasting procedural sedation occur in the ED setting, much of the literature addressing this dilemma arises from the field of emergency medicine. As per ACEP, there is no evidence suggesting a correlation between fasting, emesis, and pulmonary aspiration in healthy pediatric patients undergoing procedural sedation in the ED.<sup>65</sup> In a prospective case series by Agrawal et al, only 44% (396 of 905 patients) met published ASA/AAP guidelines.<sup>5</sup> Patients received sedation with ketamine, ketamine and midazolam, midazolam and fentanyl, chloral hydrate, or pentobarbital. There was no significant difference in adverse events, including emesis, between patients meeting or not meeting established guidelines. The authors provided an estimate of 4 episodes of

pulmonary aspiration per 1,000 pediatric sedations that do not adhere to ASA guidelines. Adverse events were associated with deeper levels of sedation. Roback et al reported a series of 2,085 children who received sedation with ketamine, ketamine and midazolam, or midazolam and fentanyl and exhibited no difference in the incidence of adverse events between children who had fasted and those who did not.<sup>6</sup> In another study, Babl et al identified 155 of 220 children who did not meet fasting guidelines for solids.<sup>66</sup> Thirty-seven children did not meet fasting guidelines for clear liquids. The median fasting duration was 4.4 hours for solids and 4 hours for liquids. Again, there was no significant difference in emesis rate between patients meeting and not meeting fasting guidelines.<sup>66</sup> As supported by ACEP, an important distinction between procedural sedation and analgesia in the ED and general anesthesia in the operating room involves the maintenance of protective airway reflexes.<sup>12,67</sup> In moderate sedation, these reflexes are maintained. The continuum of sedation from moderate into deep sedation, in which the child is not easily aroused but may respond purposefully to repeated or painful stimulation, can result in the loss of protective reflexes, particularly if airway or ventilatory assistance is required. General anesthesia is a state of drug-induced loss of consciousness in which patients are not able to be aroused and often have impaired cardiorespiratory function needing support.<sup>63,64</sup> Most of these patients require endotracheal intubation. However, aspiration can occur despite the presence of an endotracheal tube. Also, the airway manipulation involved during the process of endotracheal intubation can increase risk of aspiration.<sup>12,67</sup>

Emergency medicine physicians make note of an additional sedation level known as dissociative sedation. Dissociative sedation, as achieved with ketamine, is a trancelike cataleptic state that provides analgesia and amnesia while generally maintaining protective airway reflexes, spontaneous respirations, and cardiopulmonary stability.<sup>68</sup> In children, deep or dissociative sedation is often chosen for painful procedures performed on an urgent or emergent basis.<sup>2</sup> Thus, one of the critical decision points when planning sedation and analgesia in the non-fasting pediatric patient is the level of sedation required for the procedure at hand. Due to the continuum of sedation and the sometimes unanticipated duration of a procedure, sedating physicians should be trained and skilled in managing the next deeper level of sedation than what is planned. Physicians should be capable of administering pharmacologic agents to predictably achieve desired levels of sedation,

monitoring patients and maintaining them at desired levels of sedation, and managing complications observed during PSA.<sup>67,69</sup> Clinicians who perform pediatric sedation should obtain information on the patient's fasting status and urgency of the procedure to determine timing of sedation, target depth of sedation, and specific medications used.<sup>70</sup> Factors to consider when faced with sedating the non-fasted pediatric patient are summarized in Box 8-4. A checklist for sedation of the non-fasted child is outlined in Box 8-5.

The sedation practitioner should identify the patient's ASA risk classification as part of the pre-sedation evaluation. In general, children with ASA classes 1 and 2 can be managed outside of the operating room by medical personnel other than anesthesiologists.<sup>2</sup> The presence of severe systemic disease with definite functional limitation (ASA  $\geq 3$ ) requires the presence of a physician capable of advanced airway management. This information should factor into decisions on level of sedation and medical personnel required for non-fasting sedation.<sup>12</sup> Specific patient risk factors, including the potential for difficult or prolonged assisted ventilation, conditions predisposing to esophageal reflux and delayed gastric emptying, young age (<6 months), altered level of consciousness, and frailty or failure to thrive, should be considered when determining a candidate for sedation in a non-fasted state.<sup>12</sup>

Missshapen head, short neck, neck masses, micrognathia, tracheomalacia, laryngomalacia, stridor, drooling or impaired handling of secretions, history of prior difficult intubation, sleep apnea, congenital anomalies of the airway and neck, and conditions that limit neck mobility can imply potential airway management difficulties should sedation deepen during the procedure. The patient should be assessed for adequate mouth opening.

**Box 8-4. Factors for Consideration When Sedating the Non-fasted Child**

- Urgency/emergency of procedure
- Type and timing of last meal
- ASA status of patient
- Level of sedation required for procedure
- Estimated duration of procedure
- Experience of sedating physician
- Airway patency and assessment, including Mallampati score
- Preexisting medical conditions that slow gastric emptying

Abbreviation: ASA, American Society of Anesthesiologists.



**Box 8-5. Checklist for Sedation of the Non-fasted Child**

Determine emergency of the procedure.

Identify ASA physical status classification.

Identify risk factors for airway management.

- Craniofacial or airway abnormality
- Neck immobility
- Conditions predisposing to gastroesophageal reflux, including increased intracranial pressure, tracheoesophageal fistula, gastritis, ileus, bowel obstruction, and abdominal distension
- Age <6 mo
- Altered level of consciousness
- Impaired gag reflex

Determine timing and type of last meal.

Determine depth of sedation required and duration of sedation.

- Is procedure painful?
- Is oral contrast required?
- Must the patient be still for the procedure?
- Will sedation be required for >20 min?

Assemble sedation staff.

- Advanced airway management requires skilled sedating personnel, health care professional to complete the procedure and nursing support.

Obtain consent for sedation and procedure.

Obtain vascular access for moderate to deep sedation.

Provide monitoring appropriate for level of sedation.

- Mild/moderate: continuous ECG, SpO<sub>2</sub>, BP, RR every 15 minutes
- Dissociative: continuous ECG, SpO<sub>2</sub>, ETCO<sub>2</sub>, BP, RR, LOC every 5 minutes
- Deep: continuous ECG, SpO<sub>2</sub>, ETCO<sub>2</sub>, BP, RR, LOC every 5 minutes

Abbreviations: ASA, American Society of Anesthesiologists; BP, blood pressure; ECG, electrocardiography; ETCO<sub>2</sub>, end-tidal carbon dioxide; LOC, level of consciousness; RR, respiratory rate; SpO<sub>2</sub>, pulse oximetry.

Thyromental distance should be the width of 3 of the patient's fingers.

Mouth opening should be the width of 2 fingers. A Mallampati score should be obtained to assess visualization of the airway. Conditions that predispose to gastroesophageal reflux include elevated intracranial pressure, esophageal disease, tracheoesophageal fistula, hiatal hernia, peptic ulcer disease, gastritis, bowel dysmotility or obstruction, ileus, and significant abdominal distension (eg, ascites, organomegaly, abdominal masses, gravid uterus). Age younger than 6 months is a risk factor because infants have a predisposition to regurgitation as well as potential airway challenges and potentially exaggerated responses to sedation.<sup>70,71</sup>

Medications chosen for sedation of the non-fasting pediatric patient depend on level of sedation required (ie, minimal, moderate, dissociative, or deep) and need for analgesia and for immobility of the patient. A prolonged procedure can lead to drug accumulation such that a longer procedure, when using a drug to provide moderate sedation, may transition to a deeper level of sedation. Green et al described procedural sedation greater than 20 minutes as “extended.” Extended procedural sedation carries an increasing risk for progression to a deeper sedation level and, therefore, a greater aspiration risk.<sup>12</sup> Therapeutic prophylaxis with antacids, histamine antagonists, metoclopramide, or anticholinergics has not been shown to lower aspiration risks or improve outcomes. Such pharmacologic pretreatment is not routinely recommended by the ASA.<sup>3,72</sup>

Urgency of the procedure, ASA risk status of the patient, airway and gastroesophageal reflux characteristics of the patient, target depth of sedation needed, and known fasting status will help determine the need of a physician capable of advanced airway techniques, transfer to the operating room, and general anesthesia. If, during sedation of the non-fasted patient, the desired sedation depth or duration becomes excessive, the procedure can be delayed, sedation can be scaled back, or the patient can be transitioned to receive general anesthesia.<sup>12</sup> Alternatively, based on the pre-sedation evaluation, it may be determined the patient is not a candidate for procedural sedation and the safer option is to provide endotracheal intubation and general anesthesia.

## **Sedation for Radiation Therapy**

Radiation therapy is critical to the successful multimodal management of pediatric cancer. Children with brain tumors, sarcomas, neuroblastoma, Wilms tumor, and Hodgkin and non-Hodgkin lymphoma are often treated with radiation therapy.<sup>73</sup> Sedating the pediatric patient, ill from malignancy and concurrent chemotherapy, on a daily basis for several weeks in a location remote from the operating room in a safe and effective manner requires a well-trained sedation team, ongoing communication among all practitioners, and strict protocol adherence.

Radiation designed for cancer treatment creates ions in the tissues through which it passes, thereby causing damage to cellular DNA. To allow healthy tissues the greatest chance to repair from the ionizing effects of radiation, the total dose of radiation is divided into a series of fractions over days to

weeks. Fractionation also allows tumor cells that were in a radio-resistant phase of the cell cycle during one treatment to cycle into a sensitive phase prior to administration of the next fraction.<sup>74</sup> Photons (ie, x-rays and gamma rays) and particle radiation (ie, protons, electrons, neutrons, and alpha and beta particles) are the 2 major types of radiation therapy. Protons have a physical advantage over photons due to better sparing of normal tissues. The exact depth to which protons penetrate tissue can be controlled precisely.<sup>75</sup> Therefore, normal tissues beyond the tumor target receive very little or no radiation. Proton therapy is presently available in a limited number of centers in the United States. Although comparisons in results and side effects between protons and photons are still under investigation, some predict that it will become the standard of care.<sup>76</sup> Treatment time is generally longer than traditional photon therapy, lasting 30 to 45 minutes. Proton radiation centers can be remote from the main hospital setting, adding further challenges to safe treatment and sedation of children. Furthermore, given the obvious risk to health care professionals, no one is allowed in the room during treatment sessions, thereby necessitating remote monitoring and care.

Prior to the first radiation treatment, the child undergoes a simulation session, which often involves the creation of an immobilization device, computed tomography imaging, and multiple measurements and markings on the child's body as the radiation oncologist plans treatment. This session provides an opportunity to develop a sedation strategy to use during actual treatment sessions. Factors to consider when developing a safe sedation strategy for pediatric radiation therapy include the location of the radiation center, training and expertise of the sedation team, individual patient characteristics, and treatment prescribed by the radiation oncologist (Table 8-9).

During radiation therapy, the sedation team must function away from the relative safety provided by the operative suite or sedation center and its staff and equipment. In addition, many US proton therapy centers are freestanding, without adjacent high-level hospital care.<sup>77</sup> The sedation team should be skilled in sedation, airway management, and resuscitation. During the time of radiation delivery, the sedation team cannot stay in the treatment vault with the patient and must rely on monitoring and camera equipment to visualize the patient.<sup>76-80</sup> Due to the dangers from health care worker exposure to the radiation, adjustment of infusion pumps must rely on technology that allows remote operations or the pumps being kept in the control room with long infusion lines connected to the patient.

**Table 8-9. Considerations and Challenges of Sedation During Radiation Therapy**

<b>Radiation Factor</b>	<b>Sedation Challenges</b>
Location of radiation suite	<ul style="list-style-type: none"><li>• Remote location in the hospital</li><li>• Possible nonhospital setting (proton beam)</li></ul>
Sedation practitioner	<ul style="list-style-type: none"><li>• Remote from patient during radiation delivery</li></ul>
Pediatric patient	<ul style="list-style-type: none"><li>• Variability in age from infancy to adolescence.</li><li>• Psychologically frightening treatment.</li><li>• Must be immobile for radiation accuracy.</li><li>• Variety of body positions, dependent on tumor type and location.</li><li>• Repeated sedations (daily) required.</li><li>• May be ill from chemotherapy or coexisting illnesses.</li><li>• Change in weight may result in new simulation.</li><li>• May develop tolerance to sedation medications.</li></ul>
Treatment	<ul style="list-style-type: none"><li>• Frequency: daily for up to 6 wk.</li><li>• Length of case: 10–60 min.</li><li>• Location: TBI or abdominal radiation can cause nausea, vomiting, or diarrhea.</li><li>• Positioning: TBI or other locations may require prone positioning.</li></ul>

Abbreviation: TBI, total body irradiation.

Children of all ages require radiation therapy and may approach this treatment with anxiety, having experienced a range of procedures before radiation. Immobilization devices, particularly the plastic immobilization head cast that fits tightly over the face, can be frightening. To ensure radiation accuracy and prevent damage to healthy tissue, the patient must remain immobile for the procedure. Positioning of the patient can vary, with total body irradiation or treatment of specific areas performed partly in the prone position. This will provide challenges in airway patency and monitoring. A child may develop potentially serious intercurrent symptoms that threaten sedation stability, including an upper respiratory infection, fever, or vomiting. When this occurs, sedation risks should be balanced with the benefits of radiation therapy and risks of postponement of therapy. A patient's physical status may change over a 6-week period. Marked weight gain, often due to corticosteroid treatment, can affect the fit of immobilization devices, necessitating a new simulation session. All children will undergo repeated sedations on a daily basis, resulting in repetitive exposure to sedative medications and the risk of sedation tolerance. The type of treatment prescribed by the radiation oncologist must be considered when developing a safe individualized

sedation regimen. Most radiation treatments are provided on a daily basis (Monday through Friday) for a 6-week duration. Whenever feasible, use of agents that facilitate a rapid recovery and limiting postoperative nausea and vomiting is imperative, as NPO times coupled with prolonged recovery times can result in missed meals and further weight loss. Total body or abdominal radiation can cause nausea, vomiting, or diarrhea, affecting consideration of airway protection and pre-sedation hydration status. The length of sedation can vary depending on the use of photon radiation versus proton beam therapy. Longer cases, typical for proton beam radiation due to setup and treatment complexity, may require daily use of a laryngeal mask airway or endotracheal intubation for airway protection and are better accomplished using general anesthesia rather than procedural sedation. The duration of radiation procedures can range from 10 minutes to greater than 60 minutes. In a retrospective analysis of anesthesia-related complications at St. Jude Children's Research Hospital involving 177 patients during a total of 3,850 radiation procedures under anesthesia or sedation, a correlation was noted between duration of anesthesia and risk for adverse events.<sup>78</sup> The odds of complications during procedures greater than 60 minutes were 4.28 times that for procedures of 30 to 60 minutes; the odds of complications for procedures greater than 60 minutes were 9.85 times that for procedures less than 30 minutes. Complications were documented in 49 of the 3,833 procedures (1.3%) for which propofol-based anesthesia was used. Minor airway complications were the most common. There were no episodes of laryngospasm and no need for advanced airway interventions, including endotracheal intubation. Four factors were significantly associated with the risk of complications: procedure duration, total propofol dose, use of adjunct agents, and simulation versus actual radiation therapy. On a multivariate analysis, procedure duration and total propofol dose were the most significant factors, after adjustment for age, weight, anesthetic, and procedure type. Whether the patient was treated in the prone or supine position was not significantly associated with frequency of complications.<sup>79–81</sup> In a recent large pediatric series from a proton beam radiation center, a total of 138 children underwent 4,045 sedation or anesthesia procedures.<sup>82</sup> Three minor events occurred (a fall and 2 aspiration events), resulting in a complication rate of 0.0074%. All 3 children did well and no patient required cessation of therapy. Due to the longer duration of these procedures, these patients underwent propofol induction, placement of a laryngeal mask airway, and anesthesia with 3% sevoflurane and oxygen. Seiler et al reported on the sedation of 74 children for 1,033

procedures.<sup>80</sup> Eighty-five complications were noted for an incidence of 8.2%. Most children were sedated with chloral hydrate, meperidine, or midazolam. There was satisfactory sedation in 60%, 60%, and 82%, respectively, and there was an inability to treat in 20%, 13%, and 5%, respectively. The only significant factor predicting a successful outcome was use of propofol versus other medications. Other studies report a low percentage of complications when sedating children for radiation therapy.<sup>83,84</sup>

Historically, a variety of sedative drugs have been used to facilitate radiation treatment for children, including inhalation anesthetic agents, intramuscular and IV methohexital, ketamine, thiopental, and chloral hydrate, meperidine, or midazolam. The use of dexmedetomidine has also recently been reported.<sup>85</sup> More recently, propofol has become the standard agent used in most cases, barring individual contraindications.<sup>86-88</sup> The merits of propofol for radiation therapy include an easily titratable depth of anesthesia, maintenance of spontaneous ventilation with minimal need for airway manipulation, and rapid recovery. Still, very long procedures or radiation for retinoblastoma, which requires paralysis of the eye muscles, may require endotracheal intubation and ventilatory support.

Strict protocol adherence and a well-trained sedation team are required to provide sedation safely for children receiving radiation therapy. Consistency of the sedation team is desirable so that the team and parents and children can become familiar with one another. The use and type of sedation should be determined on a case-by-case basis, in consultation with the radiation oncologist. High-risk features for each patient should be reviewed, such as the potential need for tracheostomy prior to treatment due to abnormal airway or cervical anatomy that would render emergent endotracheal intubation difficult. Communication with the oncology team should occur if a child develops a significant upper respiratory infection that may complicate sedation or anesthesia. Standard NPO guidelines should be followed, with younger children scheduled early in the day. Strict aseptic technique is required when handling implanted central venous access devices. Monitoring should include a continuous electrocardiography, pulse oximetry, capnography, and a noninvasive blood pressure device. Visualization of the patient via cameras will assist in monitoring respirations and possible movement. All radiation suites require suction and endotracheal intubation equipment, anesthesia medications, and an emergency cart with resuscitation equipment, medications, and a defibrillator. A medication management

plan can be established during the simulation session to carry forward during treatment. If propofol is used, the sedation practitioner should be mindful of the possible development of tolerance and risk of deeper sedation during sessions exceeding 1 hour. Finally, performance of an annual simulation exercise, involving the entire staff from radiation therapists to nurses and physicians, of various patient emergencies can help address safety concerns and develop solutions.

## Summary

There are many challenges to the provision of safe and effective procedural sedation in remote sites, including significant variation in the patient population (eg, age, physical status, presence of comorbid features), clinical scenario, and locations where sedation is required. In some cases, there are obstacles related to equipment or procedure (eg, MRI, radiation oncology) that must be factored into the sedation plan. This chapter has attempted to review some of these challenges, including those related to the patient (eg, former preterm infant, non-fasted patient) and those related to the location. For the sedation practitioner, we are frequently called on to travel from our “safe zone” and venture out into various locations in the hospital. These travels require that we ensure we provide the same level of care regardless of the location. This can be accomplished by following the same procedure for the pre-sedation preparation of the patient, intraoperative monitoring, and post-procedure recovery. Access to a travelling cart for such endeavors can be extremely helpful, as most of the necessary equipment and medications can be housed in it. Prior to embarking on sedations in unfamiliar locations, a site visit should be performed to identify where the sedation practitioner will stand, where monitors will be located, and where the source is for oxygen and suction. Depending on the procedure, there may be limited access to the patient or the patient may even be covered with drapes. When considering specific scenarios, such as the patient undergoing cardiac catheterization, the effect of the sedation regimen on data collected must be considered. Given all of these concerns, appropriate planning is paramount in ensuring a successful outcome for the sedation experience and ensuring the safety of our patients.

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CHAPTER 9

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## **Non-pharmacologic Interventions in Children During Medical and Surgical Procedures**

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### **Introduction**



The primary purpose of non-pharmacologic interventions is to diminish anticipatory fear and anxiety and reduce procedural distress and pain while giving the child and family a sense of control.<sup>1,2</sup> Non-pharmacologic interventions can set the stage for all aspects of the pediatric procedure encounter. Psychologic preparation and cognitive behavioral-sensory interventions during the procedure are an integral part of care for any child scheduled for a procedure, whether the child receives a sedative medication or not. At a minimum, non-pharmacologic interventions should be used to prepare and educate children and their families in anticipation of the procedure. Preparation alone has been shown to consistently reduce pre-procedure anxiety and behavioral distress behaviors in children and families for all procedural types, ranging from noninvasive procedures such as nuclear medicine scans to invasive procedures such as bone marrow aspirates and biopsies.<sup>1,3-6</sup> Alone or as an adjunct to sedation, the use of non-pharmacologic methods like cognitive-behavioral techniques reduces distress behavior during an intrusive or painful procedure. Similarly, non-pharmacologic techniques during the recovery phase of the procedure can help calm the child while promoting patient and family satisfaction. Furthermore, effective use of these techniques may decrease the total dose of sedative or analgesic agents as well as shorten the duration during which these agents are needed. Consequently, non-pharmacologic interventions comprise a critical component of care for all phases of the procedure encounter. While specific health care personnel

are trained to provide cognitive-behavioral interventions (eg, child life), as a whole, non-pharmacologic methods are multidisciplinary in nature. In larger institutions, these services may be provided by specialized child life specialists; however, financial constraints may limit availability of such services at smaller institutions. Regardless of the setting, use of such services may also be affected by variability in scheduling and limited available time in busy radiology procedure schedules. Consequently, all personnel caring for the child receiving a procedure, with or without sedation, should be knowledgeable of the types and uses of non-pharmacologic interventions and their role in reducing anticipatory anxiety and procedural discomfort.

In this chapter, *non-pharmacologic methods* will refer to any intervention not using a medication, alone or as an adjunct to sedation, that enhances the well-being of the child and family throughout all aspects of the procedural sedation encounter. The first section provides an overview of non-pharmacologic interventions used to prepare, support, and recover patients and families before, during, and after a procedure. The use of cognitive-behavioral techniques will be emphasized. Discussion of the various approaches to non-pharmacologic interventions will be examined in the context of the 3 specific stages of the procedure: pre-procedure, procedure, and post-procedure times. The pre-procedure phase will focus on patient and family assessment, preparation, and establishment of a coping plan. The use of specific non-pharmacologic interventions during the procedure will be examined in the following section. Finally, the general support of children and their families during the procedural recovery phase will be discussed.

## Non-pharmacologic Interventions

Non-pharmacologic interventions encompass a broad range of techniques designed to reduce anxiety and discomfort (pain) before, during, and after the procedure. While most discussions on this subject refer to the use of non-pharmacologic interventions in children for acute procedural pain, these tools can be applied to all aspects of the patient care encounter. In general, non-pharmacologic interventions comprise cognitive-behavioral or physical (sensory) approaches. Cognitive-behavioral techniques help divert attention away from the procedure and may be directed at the child,

caregiver, or both.<sup>7</sup> Educating and preparing the child and parent on what to expect and do during the procedure is an example of cognitive-behavioral methods that can be used before the procedure.<sup>8</sup> Distraction techniques are the most common types of cognitive-behavioral methods used during the actual procedure. Methods of distraction include simple passive techniques in which the child's attention is redirected to a stimulus or object presented by a health care professional. Examples include showing the child a toy (eg, kaleidoscope), storytelling, or singing a song. Active (interactive) distraction techniques, on the other hand, require the child to participate. Examples include having the child blow bubbles, play a game, or interact with a computer application. Simple passive and active distraction methods are particularly effective in toddlers and preschool-aged children. More complex cognitive-behavioral strategies are useful in older children and adolescents and include guided imagery, relaxation techniques (eg, deep breathing exercises), and music therapy.<sup>7,9</sup> Physical (sensory) approaches are typically patient specific and refer to techniques that inhibit nociceptive input and pain perception.<sup>2,7</sup> Non-pharmacologic sensory methods are usually used during the actual procedure. Examples include swaddling, nonnutritive sucking, acupressure, massage, and transcutaneous electrical nerve stimulation. In any one patient, cognitive-behavioral and physical techniques may be used alone or in combination during different stages of the procedure. Choosing the most effective technique will depend on the patient's age and developmental level, prior medical experiences, and degree of pain or intrusiveness associated with the procedure. Box 9-1 outlines some of the more common cognitive-behavioral and physical (sensory) non-pharmacologic methods used in children.

While the provision of non-pharmacologic support is multidisciplinary in nature, child life specialists are health care professionals uniquely qualified and positioned to provide these interventions. Child life specialists have specific education, training, and expertise in child development and supporting children and their families during the health care encounter.<sup>10,11</sup> Child life programs are considered an integral part of patient- and family-centered care and an indicator of a high-quality integrated child health delivery system.<sup>10,12</sup> The advantage of having child life services as part of the multidisciplinary team is that the child life specialist is the team member who is able to focus solely on the psychologic preparation and support of the child and family before, during, and after a procedure.<sup>10</sup> The value of having child life services



### Box 9-1. Non-pharmacologic Interventions

#### Cognitive-Behavioral Interventions

- **Psychologic preparation:** Age-appropriate verbal and written information that describes the procedure, clarifies expectations of the patient/family, and explains what will happen, how it will feel, and strategies for coping. Play therapy may be useful for preparing the younger child, while older children will benefit more from being taught relaxation techniques.
- **Distraction—passive (patient observes):** eg, kaleidoscope, light-up toys, listening to stories or singing, watching videos.
- **Distraction—active (patient participates):** eg, blowing bubbles, reading, singing songs, playing, interactive books, computer games.
- **Relaxation techniques:** eg, deep breathing exercises, muscle relaxation.
- **Music:** The patient listens to music of his or her choice, usually with a headset (often the relaxation/distraction technique of choice for adolescents).
- **Guided imagery:** The patient concentrates and visualizes a pleasurable experience or favorite place during the procedure. This may be used to produce a hypnotic state. This tends to be particularly effective for school-aged children and adolescents.
- **Other techniques:** Peer role modeling, positive coping statements, positive reinforcement (health care professionals, such as child life specialists, or parents, identified as support people or coaches, are important in facilitating cognitive-behavioral methods).

#### Physical (Sensory) Interventions

- **Positioning:** eg, swaddling, hugging, holding
- **Cutaneous stimulation:** eg, rubbing skin, applying localized pressure
- **Nonnutritive sucking (pacifier)**
- **Sucrose water**
- **Pressure:** massage therapy, acupressure
- **Hot and cold treatments**
- **Transcutaneous electrical nerve stimulation**

in preparing children and families for a procedure has been demonstrated in the preoperative surgical setting, radiology suite, and pediatric emergency department.<sup>11,13–15</sup> Stevenson et al reported a reduction in behavioral distress before intravenous cannula placement in 4- to 7-year-olds receiving child life services.<sup>14</sup> Similar reductions in anxiety have been found in the preoperative surgical setting.<sup>15</sup> Child life programs can also provide education to other health care professionals in the use of cognitive-behavioral interventions for children and families undergoing procedures.<sup>10</sup> The following sections will discuss various non-pharmacologic modalities in the context of individual procedural stages.

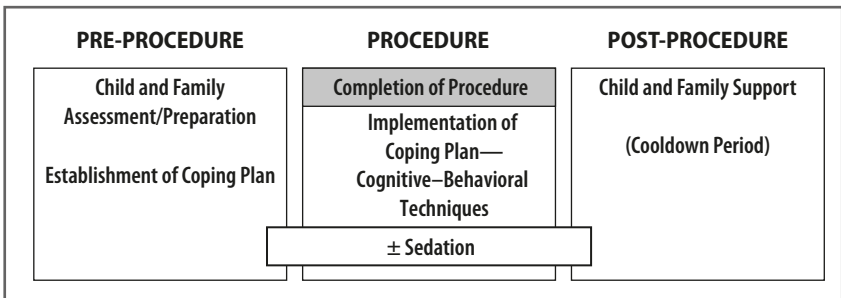
# Procedural Stages

The procedural (sedation) encounter comprises 3 distinct stages: the pre-procedural period, the procedure stage, and the post-procedure recovery period (Figure 9-1). The pre-procedural phase sets the stage and is the most important period used to prepare the child and family for the procedure and establish a coping plan. The procedural phase is when non-pharmacologic techniques are used as part of the coping plan to support and comfort the child during the actual procedure. The post-procedure phase is the recovery period when continued comfort and support will continue while reflecting on the overall experience. The next 3 sections will discuss the non-pharmacologic techniques used during these 3 phases of the procedure.

## Pre-procedure: Patient and Family Assessment and Preparation

The pre-procedure stage begins before patient arrival and ends as the patient enters the procedural phase of the encounter. The purpose of this phase is to understand the needs and capabilities of the child and family to most effectively prepare them for the procedure and, when indicated, sedation. Preparation begins prior to the visit and requires acquiring relevant information that will facilitate preparing the child and family for the procedure. Important information to have prior to arrival includes the patient's age, medical diagnosis, underlying condition, procedure type, and indications. Additionally, when planned, information on the type and depth of sedation should be obtained. Important aspects of this period include a thorough

**Figure 9-1**



Goals of non-pharmacologic interventions during the 3 procedural stages

assessment of the child and family's needs and patient and family education, as well as preparation and establishment of a coping plan.

There are a number of factors that will determine the most effective way to prepare the child and family, the effect it will have on the child, and the family's ability to cope with the medical procedure. The Stress-Potential Assessment is a tool that can be used to help navigate the needs of the patient and family. It identifies 3 variables that will influence how the child and family will respond during the encounter: child variables, family variables, and health care variables.<sup>16</sup> Child variables include the child's chronologic and developmental age, response to current and previous health care experiences, ability to communicate and function independently, and coping style. Younger age and previous negative medical experiences shape the child's pre-procedure anxiety and coping abilities during the procedure. The child's temperament is also an important factor to consider in anticipating how he or she will respond to a painful stimulus. Family variables include the family's physical and emotional availability to the child, understanding and awareness of the child's medical situation and health care needs, support systems, cultural beliefs, and willingness to communicate with the health care staff. Health care variables consist of the child's medical diagnosis and condition as well as anticipated treatments and procedures. For example, the specific needs and reactions of a patient with newly diagnosed leukemia will be different than a healthy child undergoing a laceration repair. Taking these variables into consideration when assessing the child and family will help the health care practitioner create an individualized care plan. The goal of the preparatory care plan is to decrease emotional stress and trauma related to the child's procedure. In addition, preparation should be structured to increase the child and family's ability to cope with the overall health care experience, current and future.

### *Assessment of Patient and Family Needs*

The first priority is to assess the needs of the patient and family. Knowing the patient's age and developmental level and underlying medical condition and the family's knowledge and concern about the procedure will help guide the preparation process. Patient factors include the child's age and developmental level. These factors will help determine the patient's cognitive ability to comprehend and process information. It will also give insight on how he or

she may respond to stressors in the medical environment. Younger children between the ages of 1 and 5 years are at greatest risk of having pre-procedure anxiety.<sup>17,18</sup> Another risk factor that affects the level of pre-procedure anxiety is previous traumatic medical experiences.<sup>17,18</sup> If intellectual or developmental delays are identified, it is important to determine the child's cognitive and physical capacity, preferred activities, and previous medical experiences and whether these factors will affect the child's ability to learn and cope with the upcoming procedure.<sup>19</sup> If there is an issue of language or comprehension, the family will be a great resource to help identify ways to help the child with the procedure. Developmental considerations are discussed next and outlined in Table 9-1 along with common hospital stressors.<sup>20,21</sup>

### ***Infant (Birth–1 Year)***

During the first couple months of life, the infant learns through sensory input, begins to discriminate voices and faces, and develops a strong attachment (bond) to the parent. Clear expressions of distress (pain or hunger) and happiness evolve during this period as well. Around 6 months of age, the infant develops stranger anxiety, and at about 9 months of age, separation anxiety. Consequently, parental presence and involvement are very important during this period and key factors in providing comfort and security to the infant during the visit.

### ***Toddler (1–3 Years)***

While stranger anxiety may persist during this period, the toddler displays behavior that is more independent and social. Children during this stage are egocentric and more self-conscious and may have feelings of embarrassment or shame. Imitation, play, and development of relationships outside the family are important aspects of this period. In the medical setting, allowing toddlers to “play” with various forms of medical equipment is often helpful. Toddlers are also very distractible, making distraction techniques very useful. Parental presence and participation still remain very important.

### ***Preschool (3–6 Years)***

Children during this phase are becoming more independent in their daily activities and enjoy learning and initiating tasks. Fear of failure and guilt are also part of this period. Giving children in this age group some conditional control and appropriate choices may facilitate preparation during the pre-procedure phase.

**Table 9-1. Developmental Stages in Children and Associated Hospital Stressors**

Age	Developmental Stages	Hospital Stressors
Infant (Birth–1 y)	<b>Trust vs Mistrust Stage</b> (Erikson): Infants establish a sense of trust when basic needs are met.	<ul style="list-style-type: none"> <li>• Separation from parent and attachment interrupted</li> <li>• Introduction of new people</li> <li>• Interruption of sleep and feeding routines</li> <li>• Painful events</li> </ul>
	<b>Sensorimotor Stage</b> (Piaget): Infants learn from movement and sensory input. Learning cause and effect. Establishing object permanence.	<ul style="list-style-type: none"> <li>• Mobility restricted due to medical reasons or confined to crib or room.</li> <li>• Opportunity to play and explore through the senses may be limited or restricted.</li> <li>• Overstimulating environment—startles to loud noises and sudden movements.</li> </ul>
Toddler (1–3 y)	<b>Autonomy vs Shame and Doubt Stage</b> (Erikson): Toddlers are increasingly independent in many spheres of life.	<ul style="list-style-type: none"> <li>• Choices limited</li> <li>• Independence restricted</li> <li>• Movement restricted</li> </ul>
	<b>Preoperational Stage</b> (beginning), <b>Sensorimotor Stage</b> (end) (Piaget): Toddlers show increasing curiosity and explorative behavior. Language skills improve. Can hold and recall images.	<ul style="list-style-type: none"> <li>• Limited opportunity to explore new environment</li> <li>• Limited understanding of medical equipment</li> <li>• Associates pain with people and medical equipment/supplies</li> </ul>
Preschool (3–6 y)	<b>Initiative vs. Guilt Stage</b> (Erikson): Preschoolers like to initiate play activities.	<ul style="list-style-type: none"> <li>• Play opportunities may be limited.</li> <li>• Ability to make choices is limited.</li> </ul>
	<b>Preoperational Stage</b> (Piaget): Preschoolers are increasingly verbal. Limitations in thought processes but able to understand more than one factor at a time that influences an event. Causality is often confused.	<ul style="list-style-type: none"> <li>• Magical thinking may predispose to fear of mutilation and pain.</li> <li>• May not understand why they are having the procedure.</li> </ul>

**Table 9-1. Developmental Stages in Children and Associated Hospital Stressors, continued**

Age	Developmental Stages	Hospital Stressors
School-age (6–12 y)	<b>Industry vs Inferiority Stage</b> (Erikson): School-aged children gain sense of self-worth from involvement in activities.	<ul style="list-style-type: none"> <li>• Enforced dependence</li> <li>• Loss of competence</li> <li>• Loss of control</li> </ul>
	<b>Concrete Operational Stage</b> (Piaget): School-aged children have increased ability to think logically in a physically concrete realm. Understand the rationale of the order of a series of actions and sequences.	<ul style="list-style-type: none"> <li>• Loss of mastery</li> <li>• Fear bodily injury and pain</li> </ul>
Adolescent (12–18 y)	<b>Identity vs Role Confusion</b> (Erikson): Adolescents' search for self-identity leads to independence from parents and reliance on peers.	<ul style="list-style-type: none"> <li>• Dependence on adults</li> <li>• Loss of identity</li> </ul>
	<b>Formal Operational Stage</b> (Piaget): Adolescents are capable of mature abstract thought.	<ul style="list-style-type: none"> <li>• Lack of trust</li> <li>• Fear of diagnostic outcomes</li> <li>• Worry about long-term effect on their lives.</li> </ul>

### *School-age (6–12 Years)*

School-aged children are curious by nature and want to be involved in decision-making. They typically are concrete operational thinkers and have a desire to master physical and cognitive tasks. Modesty is an important trait in this age group. Children in this age group begin to connect cause and effect and may be proactive in their response to an anticipated procedure. School-aged children need to know what will happen to them during the procedure, characteristics of the procedure, and what is expected of them. Consequently, the pre-procedure preparation should be geared to their questions and concerns.<sup>22</sup>

### *Adolescent (12–18 Years)*

Adolescence is a period of increasing independence and self-identity. Adolescents are capable of abstract thought and problem-solving. Rapid physical and emotional changes occur during this time and underscore the importance of privacy and respect in this developmental stage. Consequently, adolescents' self-esteem may be vulnerable during this period, particularly if they have an underlying medical condition. Treating adolescents with respect and facilitating their participation in medical decision-making are important aspects of pre-procedure preparation.

### *Parent Factors (Concerns and Anxiety)*

A child's level of anxiety and ability to cope with a procedure is directly related to the parents' anxiety.<sup>17,18</sup> The cause of this anxiety may stem from previous negative medical experiences, fear of the unknown, loss of control, or worry about the results of a diagnostic procedure. It has been shown that a parent's "behaviors are related to the child's ability to cope with pain and distress."<sup>23</sup> Parental criticism or excessive reassurance of the child has been shown to increase a child's distress behavior during a procedure.<sup>24</sup> Consequently, the family's concerns and anxieties are very important to address to enhance the overall success of the medical encounter. Listening to and engaging parents and promoting their active involvement in their child's care are often effective strategies in reducing their own feelings of anxiety.

### *Assessment of Procedure Characteristics*

The type and role of non-pharmacologic interventions used in children undergoing a procedure will be influenced by the degree of discomfort associated with performing the procedure, length of the procedure, degree

of immobility required, and whether sedation is used. Also, the implications behind performing the procedure in the first place (eg, bone marrow procedure to assess leukemia relapse) may be an added stress to the older child and family. A child's ability to cope with a procedure is directly related to his or her anxiety. The cause of this anxiety can stem from previous experiences, fear of the unknown, pain, loss of control, or separation from parents. When assessing how a child has coped with previous experiences, understanding how prior coping interventions were used and how effective they were may be particularly helpful in establishing a coping plan. Regardless of procedural type, pre-procedural preparation is essential to reduce anxiety and facilitate comfort during the procedure.<sup>1,4-6,25-27</sup>

Procedures are diagnostic, therapeutic, or both and fall into 1 of 2 broad categories based on degree of discomfort (pain), noninvasive or invasive, associated with conducting the procedure.

### *Noninvasive Procedures*

Noninvasive procedures are associated with minimal discomfort; depending on the age of the child, procedure duration, and degree of immobility required to successfully perform the procedure, the child may or may not require sedation. Examples of common noninvasive procedures performed on children include computed tomography (CT) scans, magnetic resonance imaging (MRI) scans, nuclear medicine scans, and radiation therapy treatments. In programs with formal sedation services, CT and MRI scans account for greater than 60% of all sedated procedures.<sup>28,29</sup>

Despite the absence of pain, noninvasive procedures like MRI, CT, and radiation therapy are often very frightening for children, particularly younger children, and the requirement for sedation is not uncommon.<sup>6,30-32</sup> In addition to the usual stressors that a child may feel being in an unfamiliar hospital environment among strangers, there are a number of factors unique to these procedures that may add stress to the child and family. Two-thirds of children not receiving sedation for MRI experience mild to severe anxiety.<sup>32</sup> Much of this distress stems from the size of the machine, noise level, confined space, and need to lie still for an extended period.<sup>32</sup> Radiation therapy procedures are also frightening to children for some of the same reasons and the fact that some treatments may need to be performed in an unpleasant position (eg, prone position).



### *Invasive (Painful) Procedures*

Invasive procedures are painful, usually intrusive, and often associated with the insertion of a device through the skin or a body orifice. Examples of invasive procedures include oncology procedures, fracture reductions, hepatic and renal biopsies, wound care, and endoscopies. A child's reaction to an invasive procedure is connected to previous experiences, especially when perceived negatively. In general, children younger than 7 years display greater levels of procedural anxiety and distress than older children.<sup>33</sup> Invasive oncology procedures, lumbar punctures, and bone marrow aspirates or biopsies are among the most common types of painful procedures performed in children. Prior to the widespread use of sedation, patients and families considered these procedures one of the most stressful parts of pediatric cancer treatment.<sup>33–36</sup> Today, procedural sedation for oncology procedures has become a standard of care for many hospitals and accounts for up to 10% to 15% of all sedations performed in organized sedation programs.<sup>28,29</sup> Similarly, most other invasive procedures in this category receive some level of sedation or analgesia or even general anesthesia. However, the value of non-pharmacologic techniques, including psychologic preparation and distraction, alone or as an adjunct with sedation, has been well described in this patient population.<sup>1,3,26,37</sup>

A subcategory of painful procedures generally falls outside the traditional view of what is considered a truly invasive procedure, due in part to the perceived lower intensity of pain (eg, voiding cystourethrograms [VCUGs]) or speed at which the procedure can be done (eg, immunizations). Regardless of the reasons, distressful or “minimally invasive” procedures consist of a variety of procedures that can be associated with significant emotional or physical distress and suffering to patients and families due to their nature, intrusiveness, or level of discomfort (pain). Many of these procedures are performed with topical anesthetics and no sedation, thereby underscoring the importance of providing non-pharmacologic techniques for comfort and support. The VCUG is one such procedure that is uncomfortable, if not painful, and intrusive and requires a child to hold still and spontaneously void on an examination table.<sup>38–40</sup> Children and families often find VCUGs very stressful.<sup>40,41</sup> More than 70% of children receiving VCUGs without non-pharmacologic support or sedation experience serious distress or greater.<sup>38</sup> Examples of other types of procedures that can result in significant distress to children and their families include laceration repair and virtually

all needle-related procedures, including the placement of intravenous (IV) catheters, immunizations, and injections of various sorts.<sup>24,42–45</sup> Use of distraction techniques can be particularly effective in these situations.<sup>9</sup>

### *Patient and Family Preparation*

“You can protect the child from information, but you can’t protect the child from the experience.” (Author unknown)

Pre-procedure patient and family preparation sets the stage for the visit, establishes trust, and is one of the most important interactions the staff will have with the child and family. Preparing the child and family with age- and developmentally appropriate information about the upcoming procedure has many benefits.<sup>46</sup> Preparation can decrease anxiety of the child and family, help the child gain mastery and control of the situation, and decrease negative behaviors that may develop after the experience. It also helps identify their understanding of the procedure and gives the opportunity to clear up any misconceptions they may have. Preparing the child and family for the procedure should, at a minimum, address 3 aspects of the encounter: what the procedure will entail (ie, what will be done, where will it take place, and how long will it last), how the procedure will look and feel (eg, appearance of the setting, discomfort or intrusiveness of the procedure), and planned coping strategies.<sup>24</sup>

Age-appropriate preoperative preparation programs have been well described, are a standard among most pediatric hospitals, and serve as an excellent example of the types of information helpful in reducing a child and family’s anxiety.<sup>17,46,47</sup> Examples of methods used during preoperative preparation include narrative information, medical play, development of coping skills, orientation to the environment, and child life preparation.<sup>17,46</sup> The value of psychologic preparation in children scheduled for noninvasive or invasive procedures has been found to have a number of benefits.<sup>1</sup> A mock scanner MRI training protocol has been shown to increase the chances of successfully completing MRI scans in children younger than 7 years without sedation.<sup>48</sup> Patient and parent satisfaction were higher in patients undergoing endoscopy when written information was provided before the visit and children were allowed to engage in therapeutic play with dolls and medical equipment prior to the procedure.<sup>27</sup> Therapeutic preparation, including a story booklet with information provided to families prior to the visit, and

play preparation just prior to the procedure, significantly reduced distress behavior in children undergoing VCUGs.<sup>25</sup>

### *General Approach to Preparation*

The child and family's understanding of the procedure is the first step in deciding what and how much information to provide. The appropriate amount and rate at which information is delivered will vary among children. Some children will be very interested in learning about the procedure and are eager to see teaching tools and ask questions. In children 7 to 11 years of age, questions about the procedure, how long it will take, and whether it will hurt are important information needs.<sup>49</sup> Continued assessment during the preparation period is important, however, as some children may become anxious and not want to continue. For many children, especially younger children who will be asleep during the procedure, details of the procedure they won't be aware of may be too much to process and may increase their anxiety. However, older children may want details of the procedure. When giving information, focus on the senses, ie, what they will see, feel, hear, and taste.

Some parents may wish to withhold information from their child when a procedure is anticipated to be frightening or painful. Giving the parent information on how preparation can be beneficial, the different tools available, and that their child's reaction will be continually reassessed may help to reassure the parent that some form of preparation will be helpful. If the child's anxiety is known to increase when more detailed information is provided, a more general approach may be more appropriate. There are times when a discussion with the parent about the procedure may occur in the presence of the child. The child's anxiety may increase under these circumstances unless the information is clarified. Parents typically know the nuances of their child's body language and behaviors, and their input will be helpful in making an assessment of their child's anxiety and the level of preparation that is appropriate.

The language used in the medical setting is often confusing for children. Words unfamiliar to children that may have a harsh sound or sound like a familiar word (eg, dye vs die) may only add to a child's misunderstanding and anxiety. When medical language is used in front of children, key words or phrases should be defined in a way they will understand. For example, children may misinterpret words spoken following an IV catheter placement when words like "flush" are used to describe the saline push. While

it is important to answer the child and family's questions honestly, caution should be used when talking about topics like pain. Pain is subjective; what is painful for one child may not be painful for another. With this in mind, if a child is told it will hurt, he or she may expect it to hurt. However, if given a range of what other children have described, it allows the child to identify his or her own experience.

There are a variety of preparation tools that can be used during the pre-procedure preparation period. Examples include pictures, preparation books, medical equipment (play and real), dolls, and stuffed animals. Other options can include teaching sheets, diagrams, verbal descriptions, and use of the Internet and various computer applications. Using a combination of these tools will allow the child to gain mastery and control. The following section and Table 9-2 discuss age-specific preparation approaches.

### *Specific Age-Developmental Preparation*

#### *Infant (Birth–1 Year)*

Infants establish a sense of trust when basic needs are met. They learn from movement and sensory input and obtain pleasure and comfort through the mouth. As noted earlier, parental anxiety directly affects anxiety of the infant. Preparing the parent by using step-by-step explanations of the procedure and how the infant may react is often very helpful.

#### *Toddler (1–3 Years)*

Children in this age group are curious and highly distractible and often want to explore their environment. Toddlers are becoming more independent and beginning to initiate play. Simple words should be used to define objects for children in this age category. Preparation picture books that feature basic photos of the environment and personnel who will be in the room may be particularly useful. Dolls or stuffed animals can be an effective way to demonstrate how the medical equipment will be used (eg, demonstration of Foley catheter placement on a doll). Children should be allowed to play with the medical equipment and demonstrate what they have learned. Distraction techniques are often very effective in this age group.

#### *Preschool (3–6 Years)*

Preschoolers are increasingly verbal but have limitations in their thought processes. For the older preschool child, this can be classified as *magical thinking* and the child may feel responsible for causing the illness. If possible,

**Table 9-2. Age-Specific Considerations for Preparation and Approach to Non-pharmacologic Support**

<b>Infant (Birth–1 y)</b>	<b>Toddler (1–3 y)</b>	<b>Preschool (3–6 y)</b>	<b>School-age (6–12 y)</b>	<b>Adolescent (12–18 y)</b>
<b>Preparation Considerations</b>	<b>Preparation Considerations</b>	<b>Preparation Considerations</b>	<b>Preparation Considerations</b>	<b>Preparation Considerations</b>
<ul style="list-style-type: none"> <li>• Learns through senses</li> <li>• Close bond to parent</li> <li>• Stranger-separation anxiety</li> <li>• Behavioral response to pain varies, may be difficult to interpret</li> <li>• Unable to communicate discomfort verbally</li> </ul>	<ul style="list-style-type: none"> <li>• Learns through senses and hands-on approach</li> <li>• Egocentric</li> <li>• Concrete, prelogical thinking</li> <li>• Reaction to painful or intrusive procedures similar and includes fight-or-flight response</li> <li>• Comprehends little preparatory information; may benefit from playing with medical equipment</li> <li>• Highly distractible</li> <li>• Beginning medical play</li> </ul>	<ul style="list-style-type: none"> <li>• Becoming more independent.</li> <li>• Magical thinking.</li> <li>• Cognitive responses to pain change during this phase but continue to be primarily behavioral and imaginary.</li> <li>• Conditional control may be helpful.</li> <li>• Distractible.</li> <li>• Enjoys medical play.</li> </ul>	<ul style="list-style-type: none"> <li>• Cause-and-effect thinking.</li> <li>• Desires control.</li> <li>• Preparation can begin days before procedure.</li> <li>• Has better understanding of procedure.</li> <li>• May be proactive response to anticipated procedure.</li> <li>• Privacy is important.</li> </ul>	<ul style="list-style-type: none"> <li>• Capable of abstract thinking, causality, and problem-solving.</li> <li>• Capable of talking about a procedure.</li> <li>• Has ability to be actively involved in decision-making.</li> <li>• Self-control and fear of losing control are important factors.</li> </ul>

**Table 9-2. Age-Specific Considerations for Preparation and Approach to Non-pharmacologic Support, continued**

<b>Infant (Birth–1 y)</b>	<b>Toddler (1–3 y)</b>	<b>Preschool (3–6 y)</b>	<b>School-age (6–12 y)</b>	<b>Adolescent (12–18 y)</b>
<b>Coping Plan Approach</b>	<b>Coping Plan Approach</b>	<b>Coping Plan Approach</b>	<b>Coping Plan Approach</b>	<b>Coping Plan Approach</b>
<ul style="list-style-type: none"> <li>• Promote parent involvement.</li> <li>• Avoid parent separation.</li> <li>• Promote calm, safe setting (ie, reduce lighting, noise, and number of personnel).</li> <li>• Use familiar items for distraction (eg, stuffed animal, blanket, parent’s voice, lullabies).</li> <li>• Use sensory comfort (eg, pacifier, touch, cuddling, swaddling).</li> <li>• Due to short attention span, have a variety of age-appropriate toys available.</li> </ul>	<ul style="list-style-type: none"> <li>• Parent involvement similar to infants.</li> <li>• Provide simple, direct instruction by using medical play.</li> <li>• Use passive distraction (eg, light-up toys, storytelling, singing).</li> <li>• Use active distraction (eg, play, medical play, blowing bubbles, pop-up books).</li> <li>• Tactile stimulation.</li> </ul>	<ul style="list-style-type: none"> <li>• Explain steps of procedure (ie, what will be seen, felt, and heard).</li> <li>• Behavioral rehearsal may be helpful.</li> <li>• Allow child to choose distraction item.</li> <li>• Use distraction techniques similar to toddlers.</li> <li>• Provide opportunity to explore medical equipment.</li> <li>• Use passive distraction (eg, storytelling, watching videos).</li> <li>• Use active distraction (eg, talking, finding objects in a book, playing with electronic devices).</li> </ul>	<ul style="list-style-type: none"> <li>• Multiple techniques are effective.</li> <li>• Behavioral rehearsal and modeling may be helpful.</li> <li>• Preparation can be more detailed. Use photos and opportunity to explore medical equipment.</li> <li>• Use passive distraction (eg, watching videos, listening to music).</li> <li>• Use active distraction (eg, talking, finding objects in a book, playing computer games).</li> <li>• Use cognitive strategies, including relaxation techniques (eg, deep breathing), imagery.</li> </ul>	<ul style="list-style-type: none"> <li>• Multiple types of cognitive-behavioral interventions may be effective, eg, relaxation techniques, music, guided imagery, comedy.</li> </ul>

preparation for this age group is most helpful when initiated the day before the scheduled procedure.<sup>4</sup> Very basic information is often useful, such as, “We are going to the doctor tomorrow to see why your foot hurts.” Define objects using simple words. Preparation picture books that include more detailed information about the environment, including staff in the environment, and how things will look and feel during various steps of the procedure are particularly effective in this age category. Dolls or stuffed animals can be an effective way to demonstrate how medical equipment (eg, Foley catheters, syringes) will be used. Medical staff should allow children to play with the medical equipment and demonstrate what they have learned while clarifying any misconceptions they have. Starting at this age, it is beneficial to play and have fun with medical equipment. For example, children receiving VCUGs can decorate a bedpan with stickers to make their own “special potty” for the VCUG. This will help build rapport between staff and the child and facilitate decreasing anxiety about the environment and procedure.

Preparation content and approach will differ greatly within this age group. A 3-year-old having a VCUG will need basic information, such as explaining that the doctor wants to take special pictures of his or her tummy or showing pictures of the radiology suite, highlighting what he or she will see and who will be in the room. Giving a 3-year-old a job to help with the procedure is important and may include playing with toys, holding legs still, and telling Mom and Dad when he or she needs to go to the bathroom. On the other hand, a 5-year-old having a VCUG will need more detailed information about each step of the procedure, incorporating what the parents may have talked about beforehand. It is also important to reassure children that they are not responsible for causing their illness or the need for the procedure.

### *School-age (6–12 Years)*

School-aged children are gaining a sense of self-worth and the ability of mature thought from involvement in numerous types of activities. They are also beginning to understand how the body works and have an increased emphasis on privacy. When talking about the procedure and exploring the medical equipment, explain how the particular body system works and how the procedure will help. Preparation for the school-aged child is most effective about 1 week before the scheduled procedure.<sup>50</sup> This allows time to process the information, formulate questions, and practice coping skills.

### *Adolescent (12–18 Years)*

The adolescent is capable of mature, abstract thought and is searching for his or her self-identity, which leads to independence from parents and a greater reliance on peers. Adolescents have a heightened awareness of their body and a need for privacy. If sedation is planned, a common fear is that they may wake up during the procedure. Reassurance and a description of why the procedure needs to be done and how it will be done, including the level of sedation, are helpful. Verbal explanations tend to be the primary mode of preparation for adolescents, but they can also benefit from seeing photo books, diagrams, and the medical equipment. They should be assured that their privacy will be respected as much as possible to lessen any potential stress from fear of embarrassment.

### *Establishment of the Coping Plan*

Development of coping skills or the coping plan for the procedure is one of the most important purposes of the pre-procedure encounter (see Table 9-2).<sup>51</sup> A child's ability to cope with procedures is influenced by his or her memory of past painful procedures.<sup>23</sup> The development of a coping plan can address these issues and help improve the experience and ability to positively cope with future procedures. It provides a sense of comfort and reassurance by addressing the environment and potential pain the child may have. Including the child in the development of this plan enables the child to have a sense of control and a feeling of pride for completing the procedure. Seven elements to consider when creating a coping plan for children and adolescents are

1. **The support person:** A support person should be identified. The function of the support person is to focus his or her attention on the child and provide support and distraction throughout the procedure.
2. **Parental presence:** Parents may or may not want to be present during their child's procedure. Assess parents' comfort level for being present and the role they wish to take. Parents may desire to be the support person or simply be present in the room during the procedure.
3. **A safe environment:** The need for establishing a safe environment for the child cannot be overemphasized. If the child is hospitalized, use a treatment room for procedures, especially for the school-aged child and younger. The child's room, crib, or bed should be seen as a safe place where no procedures are performed. Older children can be given the



choice of their room or a specific treatment room. Use comfort positioning to avoid restraining a child. Attention to the setting's lighting and temperature should be given.

4. **A calm environment:** A calm setting can help ease a child and family's stress and anxiety. Attention should be paid to the environment's sights and sounds, including the television volume, monitoring equipment appearance and sounds, and medical personnel numbers and conversations.
5. **Distraction techniques:** Distraction techniques may be provided by medical personnel (eg, child life specialist) or a parent. It is a good idea to have a variety of age-appropriate distraction tools from which the child can choose. Distraction techniques can be divided into 2 categories, interactive (active) or passive, based on the role of the patient and support personnel.<sup>8</sup> Interactive distraction involves the child taking an active role in the activity. Examples include the child reading a book, playing with toys, taking deep breaths, or using an interactive computer application.<sup>8</sup> When using passive distraction, the activity is done for the child with the intent to encourage calming behaviors. During passive distraction, the health care professional actively distracts the child by using pictures, singing, talking, or reading a story. Choosing what type of tool to use will depend on the type of procedure, degree of pain, and level of immobility needed and whether sedation will be used. Passive distraction is most appropriate for procedures requiring high levels of stillness to be successfully completed. Interactive distraction will be more appropriate for procedures where some movement can be tolerated.
6. **The child's role:** Identify and clarify with the child the expectations of his or her role and what the child would like to do during the procedure. Involve the child in the procedure by giving him or her appropriate choices such as, "Where would you like to sit, on the bed or in your mom's lap?" When possible, some children may want to watch the procedure, for example, during placement of an IV catheter. Giving the child a choice of distraction technique is important, as some children may express a preference for active or passive distraction.
7. **Procedural pain and discomfort:** The discomfort and invasiveness of the procedure are very important qualities in determining what non-pharmacologic methods will be effective. In addition to distraction

techniques, there are a number of products available to minimize the pain a child experiences, including sucrose water, topical anesthetic agents, and other sensory modalities. Children who have not used these tools before will need to learn how they will work. When using topical anesthetic agents, allow the child to test the numb area by touching it and comparing it with an area to which the cream or spray was not applied.

## **The Procedure Stage: Initiation/Implementation of the Coping Plan**

### *General Approach*

When providing cognitive-behavioral support during the procedure, there are several general approaches that can be used to make the coping plan successful.

1. Implement the coping plan that was established with the child and family.
2. Assess the child's reaction throughout the procedure and modify the coping plan as needed. Intensify or introduce a new non-pharmacologic technique (eg, deep breathing, new toy) when the child's interest has waned and when a noxious stimulus is anticipated or occurs.
3. If a child is engaged in distraction, don't pull his or her attention away unless it is to communicate the next step or that something new is about to occur. Ideally, the support person is the child's "focal point" and will inform the child of each step to keep attention focused away from the procedure. If the child changes his or her mind about watching the procedure, allow the child to look.
4. Reassurance during the procedure is important. A child's anxiety is better controlled with distraction and verbal encouragement such as, "You are doing a good job holding still." A child's anxiety may increase when being told, "It's OK," as it may be inconsistent with what he or she is actually feeling or suggest that something is wrong.
5. To promote a calm environment, limit the amount of talking and noise in the room. If the child is anxious with medical equipment, such as procedural supplies, bring only the necessary equipment and supplies into the room and only when the procedure is ready to begin. When sedation is planned, if possible, wait until sedation has taken effect before bringing supplies into the room or beginning the first part of the procedure.

Relatively simple steps (eg, removing a transparent medical dressing prior to a lumbar puncture) may heighten the distress in an non-sedated child who was expecting to be sedated for all aspects of the procedure.

6. The younger child may be confused when he or she is told, “It’s all done.” The poke may be done, but the IV catheter may still need to be secured. A more effective statement may be, “We are almost done. I just need to put a bandage on your hand and then we will be all done.”<sup>16</sup> Also avoid telling a child the “worst part is done.” While staff may see Foley placement for a VCUg as “the worst part,” for the child it may be voiding on the table.
7. Encourage and praise the child throughout the procedure.

### *Approach Based on the Procedure Type*

Non-pharmacologic interventions during the procedure should be tailored to the child’s age and developmental level and the type of procedure being performed. Importantly, the procedural characteristics should be known, including the degree of pain and duration and level of stillness required. The environment should be made as child-focused as possible, and the role the parents will play should be understood. Regardless of the type of procedure, distraction is the simplest, most widely used and effective cognitive-behavioral intervention to reduce anxiety and procedural-related distress in children.<sup>45</sup>

### *Noninvasive Procedures*

Whereas the non-pharmacologic focus for invasive procedures is reducing procedural pain, the emphasis for noninvasive procedures is often the setting. How the child and family perceive the environment plays a particularly significant role in affecting their pre-procedural psychologic state and level of satisfaction.<sup>52,53</sup> The effect of the setting in increasing a child’s and family’s anxiety, particularly in children younger than 2 years, affects the ability to successfully perform the procedure without sedation.<sup>6,32</sup> Given the intimidating appearance of imaging equipment like MRI and CT, the setting should be as child-friendly as possible.<sup>53</sup> Parental involvement is very important, as their presence, particularly for younger children, can help reduce the child’s anxiety.<sup>6</sup> Age-dependent distraction techniques are particularly helpful in younger children for shorter procedures like CT and may include items like a pacifier, toy, or blanket. Use of audiovisual systems for MRI reduces

anxiety and the need for sedation in older children.<sup>31,54</sup> Lemaire et al reported a greater than 30% reduction in sedation requirements for MRI in children 4 to 10 years of age when using an audiovisual system.<sup>31</sup>

### *Invasive Procedures*

The goal of non-pharmacologic interventions for invasive procedures is to maximize comfort and minimize pain.<sup>1,26</sup> In their report on procedural pain management in children with cancer, Zeltzer et al state: "Success will be manifested by the child who is not afraid of subsequent procedures and not merely by a child who can be held still for a procedure."<sup>26</sup> As stated earlier, deep sedation or general anesthesia has become the standard of practice in many centers for invasive procedures in children, particularly invasive oncology procedures. However, in some circumstances, limitations in personnel or resources or the patient's underlying medical condition may prohibit the use of deep sedation or general anesthesia. Distraction with or without sedation is one of the most common cognitive-behavioral approaches used to treat acute procedural pain.<sup>9,45</sup> The type of distraction technique used for invasive procedures varies in complexity and range from a single passive form of distraction (eg, kaleidoscope for venipuncture) to combined interventions like concentrating on breathing, imagery, and non-procedural talk for invasive oncology procedures.<sup>9,55</sup> In a meta-analysis, Kleiber and Harper found that distraction reduces displays of acute behavioral distress in most children during painful procedures.<sup>9</sup> Combining non-pharmacologic techniques with sedation in children who remain conscious may be very effective in reducing distress behavior. Kazak et al found that the combination of sedation and analgesia (ie, midazolam and morphine) with cognitive behavioral therapy in children for pediatric oncology procedures proved superior to sedation and analgesia alone in reducing parents' perception of procedural distress.<sup>56</sup> In addition, the study highlighted the importance of implementing a multidisciplinary systematic approach for managing acute procedural pain in children with oncologic diseases.<sup>56</sup>

Distressful procedures have the potential to result in mental or physical suffering in children and their families unless non-pharmacologic interventions are used. Distraction techniques (eg, using party blowers, listening to a talking bear, watching a cartoon) reduced signs of behavioral distress and enhanced coping skills in children ranging in age from 2.5 to 7 years

during VCUGs.<sup>57,58</sup> Similarly, cognitive-behavioral interventions in children receiving laceration repair reduced anxiety and distress behavior in patients and lowered parents' perceptions of procedural distress in their child.<sup>43,44</sup> In children undergoing laceration repair, Sinha et al reported that music was the distraction method of choice in children overall, with 63% of older children (>10 years) preferring music compared with 39% of younger children (<10 years).<sup>43</sup> In this same study, younger children also had a high preference for video games and cartoon videos—29% and 27% of the time, respectively.<sup>43</sup> Age-appropriate distraction with or without sedation appears to be the most effective non-pharmacologic technique in reducing anxiety, pain, and stress behavior in children receiving needle-related procedures.<sup>42,45</sup>

## The Post-procedure Stage: Recovery

Non-pharmacologic interventions should be continued to support and comfort the child and family during the post-procedure recovery period. If the child is upset during the recovery phase, he or she may benefit from a cooldown period in which the child (and family) is provided time to settle and adjust after the procedure. To help calm an upset child, encourage the parents to hold and comfort the child as soon as possible. Reintroduce familiar items like toys to redirect the child's attention and lower the degree of lighting and noise in the room if possible. If the child continues to have difficulty calming, it may be beneficial for health care personnel to leave the room, allowing the child and family to be alone. Allowing time for a cooldown period is often helpful, sometimes even if for just a few minutes.

The child's overall experience will affect how he or she copes with future procedures. In an attempt to positively affect the child's memory, explore with the child and family what went well during the procedure. The discussion may include what helped address pain, eg, topical anesthetic agents, taking deep breaths, watching the procedure, or playing a game. If something did not appear to go well, explore the child and family's perspective and identify what may help in the future.

## Summary

Non-pharmacologic interventions should be implemented to prepare and support all children and families scheduled for a procedure, whether they receive a sedative agent or not. Psychologic preparation before the procedure sets the stage for the visit and is particularly effective in attenuating anxiety and reducing distress behavior in children and families. At the end of the preparation period, a coping plan for the procedure should be established. Cognitive-behavioral and sensory interventions during the procedure are helpful alone or as adjuncts to sedation in reducing signs of procedural distress in children. In younger children, simple passive and active distraction techniques are particularly effective in redirecting a child's attention away from the procedure. In older children, combinations of cognitive-behavioral interventions like relaxation techniques and listening to music are often preferred and successful in reducing procedural discomfort. Providing non-pharmacologic support to children and their families is best approached and most effective when delivered in a multidisciplinary manner.

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CHAPTER 10

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## Topical and Local Anesthetic Agents

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### Introduction



Local anesthetics are an important part of procedural sedation. Not only are they effective analgesics during and after painful procedures, but they can substantially reduce the overall sedative medication requirement and thereby potentially reduce cardiovascular (CV) and respiratory side effects. In specific circumstances, local anesthetics may even be applied to the respiratory and oropharyngeal mucosa to reduce irritation during upper gastrointestinal endoscopy or bronchoscopy. They play an important role in improving the experience of intravenous (IV) cannula placement, which remains one of the most challenging aspects of administering sedation and analgesia to children. Even when the sedation regimen starts with the oral, transmucosal, or rectal route of administration of a sedative agent, IV access is frequently still required to provide supplemental sedation and immediate access to treat adverse physiological effects should they occur. In adults, the pain of IV cannula insertion is generally mitigated by subcutaneous injection of a local anesthetic (usually lidocaine) with a small (30-gauge) needle. Until recently, subcutaneous injection was the only way to bypass the waterproof stratum corneum and provide effective analgesia of the skin. Over the last 20 years, a number of commercially available topical creams and devices can provide reliable skin analgesia without the use of a needle and with increasingly shorter onset times. This chapter reviews the basic physiology and pharmacology of local anesthetic agents, use of topical or transdermal delivery systems for IV cannula placement, prevention of pain with injection

of propofol, use of local anesthetics in the oropharyngeal region to facilitate endoscopy and bronchoscopy, and identification and treatment of local anesthetic systemic toxicity (LAST).

## Local Anesthetic Agents

There are 2 chemically distinct classes of local anesthetics: amino esters and amino amides. Amino esters include procaine, chlorprocaine, benzocaine, and tetracaine, while amides include lidocaine, mepivacaine, prilocaine, bupivacaine, levobupivacaine (not available in the United States), and ropivacaine. These 2 classes of local anesthetic agents differ in their site of metabolism, plasma half-lives, adverse effect profile, and allergic potential. Amino esters are metabolized in the plasma by cholinesterases, while amino amides are metabolized in the liver. Given their metabolism, the half-life of amino esters is relatively constant across all age ranges, as the plasma cholinesterases are distributed in body water. On the other hand, because amides are dependent on hepatic metabolism, there are significant age and developmental differences in their metabolism.<sup>1,2</sup> *P*-aminobenzoic acid is a metabolite of amino ester breakdown and may result in allergic reactions, whereas amino amides rarely cause allergic reactions. In clinical practice, these reactions are very rare. When a patient reports an allergy to a local anesthetic agent, it is most often a hemodynamic response to the epinephrine that is frequently added to the solution. There is no risk of allergic cross-reactivity between the 2 classes of local anesthetic agents; in rare case of true allergy, a local anesthetic from the other class can be used.

Local anesthetic agents differ in intrinsic potency, onset of action, duration of action, and ability to produce differential sensory and motor blockade. Regardless of their chemical structure (ester vs amide), local anesthetics block sodium channels in the nerve membrane and prevent depolarization. The non-ionized portion of the local anesthetic agent penetrates the lipid membrane, while the ionized portion reversibly blocks the inner aspect of the sodium channel. Potency is determined primarily by lipid solubility. Agents with a higher potency (ie, bupivacaine, tetracaine, and ropivacaine) have a higher lipid solubility partition coefficient (ie, are more lipid soluble).<sup>3</sup> Onset of action of a local anesthetic agent is determined primarily by the *pK<sub>a</sub>* (acid dissociation constant).<sup>4,5</sup> In general, the *pK<sub>a</sub>* of local anesthetic

agents is close to the physiological range, varying from 7.6 to 9.1. The closer the pKa is to the physiological pH of 7.4, the more rapid the onset of action because there is a greater percentage of local anesthetic in the non-ionized form, thereby promoting penetration of the nerve membrane. Lidocaine has a pKa of 7.7, which means that 35% of the drug is non-ionized at a pH of 7.4, resulting in a relatively rapid onset of blockade. In contrast, tetracaine has a pKa of 8.6 and, therefore, only 5% is in the non-ionized form at a tissue pH of 7.4, resulting in a slower onset of blockade.

Duration of action of local anesthetics is determined primarily by the degree of protein binding.<sup>6</sup> Local anesthetic agents bind to protein receptors in the sodium channels. A greater degree of protein binding produces a longer-lasting blockade of sodium channels and a longer duration of action. Bupivacaine, tetracaine, and ropivacaine are all extensively protein bound and are long-acting local anesthetic agents. Vasodilation can also affect duration of action by removing the local anesthetic more quickly from the site of action.<sup>7</sup> Vasodilation with lidocaine is a good example of this and explains why epinephrine is frequently added to commercial preparations of lidocaine to prolong its duration of action. The degree of motor and sensory fiber sensitivity varies between various local anesthetic agents. Bupivacaine and ropivacaine tend to produce more sensory and less motor blockade. The strength or extent of the block provided by any local anesthetic can be increased by increasing the concentration or volume of the local anesthetic.<sup>8</sup> However, higher plasma concentrations of the local anesthetic agent will also be achieved, thereby increasing the risks of toxicity (see Local Anesthesia Systemic Toxicity: Recognition and Treatment on page 216).

Local anesthetic preparations containing epinephrine (usually 5 µg/mL or a concentration of 1:200,000) are commercially available for agents such as lidocaine or bupivacaine or may be added to the local anesthetic solution prior to administration. The vasoconstrictive properties of epinephrine decrease the vascular absorption of the drug, thereby increasing the number of anesthetic molecules available to diffuse into the nerve membrane.<sup>9</sup> Epinephrine is also absorbed into surrounding vessels and decreases systemic absorption and plasma concentration of the local anesthetic. This effect results in the common clinical practice of limiting the dose of lidocaine to 5 mg/kg without epinephrine and up to 7 mg/kg when epinephrine is added to the solution. The efficacy of epinephrine in prolonging duration of action depends on the local anesthetic agent and site of administration.

For peripheral nerve blockade and skin infiltration, epinephrine prolongs the duration of action of all local anesthetic agents.<sup>10</sup> Although there is limited evidence-based medicine, it is generally recommended that epinephrine-containing local anesthetic agents not be injected into an area supplied by an end artery such as the finger, toe, pinna, or penis because prolonged vasoconstriction and inadequate perfusion can result.

Epinephrine can also be used as a marker for inadvertent intravascular injection. This is especially relevant when large doses of local anesthetic agents are administered. Although gentle aspiration is recommended prior to injection and intermittently during injection, even with negative aspiration for blood, there is the potential for inadvertent intravascular or systemic administration. For highly vascular areas, a “test dose” with epinephrine is frequently used as an early identification of such a problem. When epinephrine is injected intravascularly, increases in heart rate, blood pressure, and ST-T wave changes can be identified on the electrocardiogram.<sup>11</sup>

## Topical Anesthetics for Needlestick Procedures

The stratum corneum provides an effective barrier to aqueous local anesthetic agents, and until the early 1990s, cutaneous analgesia for IV catheter placement could only be achieved by injecting the local anesthetic agent directly into the skin. After it was demonstrated in 1980 that topical anesthesia for laceration repair could reliably be achieved with placement of an anesthetic solution containing tetracaine, epinephrine, and cocaine into a wound, investigators began actively researching ways to transport local anesthetic agents across intact skin.<sup>12</sup> New forms of topical anesthesia have been developed over the last 20 years by changing the physical properties of the local anesthetic preparation to make them more lipophilic (eg, eutectic mixtures, liposomal preparations) or finding non-painful ways to the disrupt the epidermis to make it easier for the local anesthetic to penetrate the stratum corneum (eg, iontophoresis, jet-propulsion injectors). While the earliest commercially available topical anesthetic agents required a long period of skin exposure (usually >60 minutes) to be effective, newer creams and devices, developed within the last 10 years, are effective within 20 to 30 minutes. This reduction in onset time has made them more practical for use in busy clinical settings.

## Topical Creams and Gels

### *Eutectic Mixture of Lidocaine and Prilocaine*

EMLA cream (AstraZeneca, Wilmington, DE) was the first topical anesthetic commercially available for use on intact skin. EMLA is a mixture of the local anesthetics prilocaine and lidocaine, which, when combined in equal amounts (eutectic mixture), form a liquid at room temperature. EMLA remains the most extensively studied topical anesthetic and has been found to be effective in reducing pain of a number of superficial cutaneous procedures. A meta-analysis of 7 well-controlled trials in children and adults demonstrated that EMLA cream reduces the pain of venipuncture and venous cannulation in 85% of the population.<sup>13</sup> Numerous other publications demonstrated its efficacy in reducing pain for other needlestick procedures such as lumbar puncture, heel stick, immunization, and circumcision. Its widespread use, however, has been hampered by its relatively prolonged onset time (60–90 minutes) and its propensity to cause cutaneous vasoconstriction, which can make venous cannulation more difficult. Although 60 minutes is the minimum recommended application time by the manufacturer, longer application times (>90 minutes) are generally associated with better quality of analgesia. Even with longer application times of up to 3 to 4 hours, depth of penetration is generally no more than 6 mm.<sup>14</sup> When deeper analgesia is required, additional subcutaneous infiltration with local anesthetic agents is generally necessary.

A rare but potentially dangerous side effect of EMLA is its potential to cause methemoglobinemia, especially in neonates and infants. One of the metabolites of the local anesthetic prilocaine has the ability to oxidize the iron moiety of the hemoglobin molecule from the normal reduced ( $2^+$ ) state to the  $3^+$  state, causing methemoglobinemia. Although the body is able to convert this back to the  $2^+$  state via the methemoglobin reductase enzyme, neonates and infants have reduced enzyme function given hepatic immaturity and higher levels of fetal hemoglobin, which is more sensitive to oxidant stress. In clinical practice, reports of methemoglobinemia related to the prilocaine in EMLA are exceedingly rare, occurring primarily in neonates or susceptible individuals with large surface area exposure or application for a prolonged period. Therefore it is essential to limit the surface area to which it is applied according to the manufacturer's instructions.

### *Amethocaine (Tetracaine) Gel*

Amethocaine gel (Ametop Gel, Smith & Nephew Healthcare Ltd, Hull, UK) is a topical aqueous gel preparation of 4% amethocaine (tetracaine) that is widely available in Europe and Canada but is not available in the United States. Amethocaine gel offers several potential advantages over EMLA cream, including rapid onset of analgesia within 30 to 45 minutes, prominent vasodilation at the application site that may facilitate vascular access, and longer duration of anesthesia (approximately 4–6 hours) due to a depot effect in the stratum corneum. Additionally, no systemic toxicity has been noted after amethocaine gel application, in contrast with the risk of methemoglobinemia related to prilocaine.<sup>15</sup> Although amethocaine gel is not currently available in the United States, a topical preparation containing the more lipophilic ester local anesthetic, tetracaine, mixed with lidocaine is commercially available in the United States as the Synera patch (see Lidocaine-Tetracaine Patch on the next page).

### *Liposomal Lidocaine*

Liposomes are microscopic multilamellar vesicles containing several lipid (phospholipids and cholesterol) bilayers dispersed in an aqueous medium. The liposomal structure enhances penetration of the epidermis and protects against rapid degradation of the local anesthetic agent, prolonging duration of analgesia. Tetracaine was the first local anesthetic to be encapsulated into a liposome to facilitate penetration through the stratum corneum, but a commercial preparation of liposomal tetracaine has not yet been marketed. Instead, a liposomal version of 4% lidocaine was developed and subsequently marketed as an over-the-counter preparation (LMX 4, Ferndale Labs, Ferndale, MI). Incorporation of lidocaine into a liposomal vehicle speeds analgesic onset to approximately 30 minutes and negates the need for an occlusive dressing, although most health care professionals generally cover the cream with a dressing to keep it in place. The excellent safety profile of this agent led the US Food and Drug Administration (FDA) to approve LMX 4 (previously marketed as ELA-Max 4%) for over-the-counter use. Several recent prospective randomized trials in children and adults demonstrated no clinical or significant difference in efficacy between liposomal lidocaine 4% applied for 30 minutes and EMLA 5% cream after a 60-minute application.<sup>16–18</sup> In one study, the procedural success rate for venous access was higher with liposomal lidocaine 4% compared with placebo.<sup>17</sup> The safety and adverse effect profile of liposomal lidocaine 4% is similar to other creams and

gels. Adverse events are usually limited to pallor, redness, and mild pruritus at the application site.<sup>18</sup> Although it is currently recommended for children older than 2 years, a recent study in newborns using 1 g topically prior to venipuncture demonstrated no adverse effects. Measured lidocaine plasma levels drawn with the same venipuncture were all within acceptable limits (<300 ng/mL).<sup>19</sup>

### *Lidocaine-Tetracaine Patch*

The Synera patch (Galen US Inc, Souderton, PA) is a unique delivery system that uses a patented controlled heat-assisted drug delivery system to accelerate the onset of cutaneous analgesia to 20 minutes (Figure 10-1). It consists of a 2.5" × 3.0" patch containing a eutectic mixture of 70-mg lidocaine and 70-mg tetracaine in a ratio of 1:1 by weight, a bio-adhesive layer, and a heating element that is activated by oxidation on exposure to ambient air, generating a controlled amount of heat (39°C–41°C) under the patch. This heating accelerates the solubility, diffusion, and analgesic onset time of the 2 local anesthetic agents. Prospective controlled trials in adults and children (3–17 years of age) have demonstrated that a 20-minute application of the Synera patch (originally named the S-Caine Patch) produced effective dermal analgesia for vascular access.<sup>20–22</sup> Adverse effects were described as transient, consisting of mild erythema, and very slight edema at the site of application in a few patients that was not statistically significant from that seen with a placebo patch. This "mild erythema" was actually the result of cutaneous vasodilation caused by skin warming and the vasodilator effects of tetracaine. Although no studies have shown a statistically significant improvement in venous catheter insertion success with the Synera patch over other topical anesthetic agents,

**Figure 10-1**

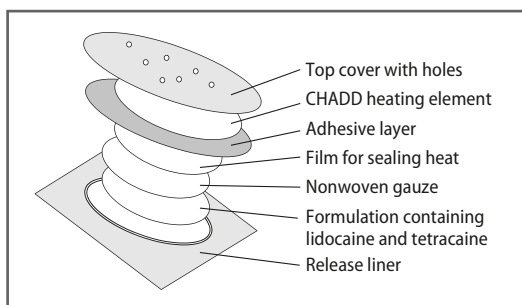


Diagram of the Synera patch demonstrating the patented controlled heat-assisted drug delivery system that accelerates onset of cutaneous analgesia to 20 minutes. The patch consists of a disc containing a mixture of lidocaine and tetracaine, a bio-adhesive layer, and a heating element that is activated by oxidation on exposure to ambient air. Reprinted by permission of Dove Medical Press, Ltd, from Tadicherla S, Berman B. Percutaneous dermal drug delivery for local pain control. *Ther Clin Risk Manag.* 2006;2(1):99–113.



vasodilation is a desirable characteristic when attempting venipuncture or venous cannulation in children. The manufacturer recommends that the patch be removed no longer than 30 minutes after placement; however, the depth of analgesia continues to increase up to 90 minutes after patch removal.<sup>23</sup> This is speculated to be due to the depot effect in the stratum corneum and longer duration of analgesia of tetracaine.

### *Jet-Propulsion Injections*

Jet injectors are handheld, needleless devices that use a compressed gas power source to propel a stream of local anesthetics through the epidermis to the dermal layer within seconds. The J-Tip injector (National Medical Products, Inc, Irvine, CA) is an FDA-approved small disposable syringe device that delivers lidocaine at a maximum capacity of 0.5 mL to a depth ranging from 3 to 8 mm (Figure 10-2). The nozzle of the injector is placed tightly against the skin, and the trigger device is activated to release the compressed carbon dioxide gas and rapidly eject lidocaine through a micro-orifice into the dermis and subcutaneous tissue. Although this device delivers a less painful subcutaneous injection of the local anesthetic agent when compared with a hypodermic needle, it may not provide consistent skin anesthesia for vascular cannulation due to diffusion of the pressurized drug into a larger tissue volume.<sup>24–26</sup> A large randomized study involving 400 adults evaluated lidocaine dose response, tolerability, and cost-effectiveness of the J-Tip injector relative to placebo and control (no lidocaine) for pain relief associated with insertion of an 18-gauge cannula into the dorsum of the hand.<sup>25</sup> A total dose of 0.5 mL of 2% lidocaine produced significantly greater analgesia compared with 1% lidocaine, saline placebo, and control but was not entirely painless. Technical failure of the J-Tip device (ie, inadequate dispersal of local anesthetic agent into the skin) occurred in 10% of patients, and failure of vein cannulation occurred in 17% of patients. The jet-injection device resulted in transient local hyperemia in 13% and

**Figure 10-2**



A jet-propulsion device for topical dermal analgesia. Courtesy of National Medical Products, Inc.

minor bleeding in 17% of the patients. Results from a randomized controlled trial in 116 children, ranging in age from 7 to 19 years, demonstrated that the administration of 0.25 mL of 1% buffered lidocaine with the J-Tip device 1 to 3 minutes prior to IV cannulation produced significantly greater analgesia when compared with EMLA cream applied for 60 minutes.<sup>27</sup> There was no difference between the 2 treatment groups in the success rate of venous cannulation, and 84% of patients reported no pain with J-Tip lidocaine application, compared with 61% who reported pain with the removal of the occlusion dressing of EMLA ( $P < 0.004$ ). A similar study involving school-aged children and adolescents in the emergency department compared the administration of 1% buffered lidocaine via J-Tip and a 30-minute application of LMX 4 and demonstrated improved analgesia with the J-Tip device.<sup>28</sup> In general, jet-injector devices provide ease of use and rapid analgesia and have the advantage of potentially protecting health care professionals from accidental needle injuries.

### *Vapocoolant Spray*

Vapocoolant sprays have been available since the 1950s but have only recently been used as an analgesic for needlestick procedures. Due to the short duration of action (<60 seconds), they tend to be most effective for intramuscular and subcutaneous injections (eg, allergy testing) but have also been used prior to venous cannulation. Studies in adults and children have demonstrated efficacy of vapocoolants as an analgesic for immunization<sup>29–31</sup> and IV cannula insertion.<sup>32,33</sup> A randomized trial in school-aged children found that pretreatment with the vapocoolant spray Fluori-Methane produced analgesia equivalent to EMLA cream for prevention of pain related to immunization.<sup>30</sup> Although used successfully for a number of years, Fluori-Methane has recently been replaced by a similar nonflammable vapocoolant called Pain Ease (Gebauer Company, Cleveland, OH), which can also be used on minor open wounds and intact mucous membranes. A recent randomized controlled trial in the pediatric emergency department comparing Pain Ease with ice prior to IV cannulation demonstrated a significant reduction in pain and improved patient experience with the vapocoolant.<sup>33</sup> Although the cooling action did produce transient vasoconstriction, IV insertion success was 83% (higher than expected).

Vapocoolant preparations can be sprayed directly onto the site or placed on a cotton ball immediately prior to application. Duration of application is generally from 4 to 10 seconds or until the skin turns white but no frost has

formed. The liquid is allowed to dry for 1 to 2 seconds before the procedure is performed, which must be done quickly before the effect dissipates. A video demonstrating the application and effectiveness of vapocoolant prior to immunization (combined with distraction) was recently released by the University of California, San Francisco, School of Nursing and can be viewed at <http://vimeo.com/81836551>. Advantages of this technique are short application time, convenience, and low cost (approximately \$0.50 per application). Skin reactions have been noted with agents containing ethyl chloride but are rare because of the rapid evaporation of these agents. Frequent spray use can cause hypopigmentation and atrophic scarring.

## Miscellaneous Applications

### Reduction of Propofol Injection Pain

Injection of propofol for procedural sedation can cause considerable pain that is not easily treated with analgesic medications such as fentanyl or morphine. In a systematic review, 70% of patients reported some degree of pain with injection of propofol.<sup>34</sup> This can be particularly distressing for parents and children when propofol is the primary drug used for initiation of procedural sedation. Recent studies have elucidated receptors that mediate this pain and have pointed to the most effective strategies in reducing it. Injection pain with propofol is mediated by activation of transient receptor potential (TRP) channels, the receptors associated with visceral pain.<sup>35</sup> Transient receptor potential channels are a family of ion channels that are selective for calcium and magnesium but not sodium and are located throughout the central and peripheral nervous system. The TRP vanilloid (TRPV) channels are activated by capsaicin, the substance in hot chili peppers. In cultured dorsal root ganglion neurons, propofol activates TRPV1 and TRPA1 receptors (mechanical stress sensors), causing the release of calcium gene-related peptide, a mediator of neurogenic inflammation.<sup>35</sup> The pain associated with activation of the TRP receptors is transmitted via C-fibers and is minimally responsive to opioids but can generally be ameliorated by local anesthetics.

In many studies, some efficacy in blunting the pain associated with propofol was provided by the pre-administration of lidocaine. When administered as a rapid IV bolus, efficacy may be limited. To maximize its contact time with

the vascular system and, hence, its efficacy, a modified Bier block has been used. This technique involves the use of an occlusive tourniquet above the site of administration of the local anesthetic for 30 to 120 seconds prior to administration. In a systematic review by Picard and Tramèr, a modified Bier block with lidocaine (0.5 mg/kg) was found to be the most effective method to reduce this injection pain, with 60% reporting that this prevented injection pain.<sup>34</sup> All other modalities tested, including administration of opioids, IV lidocaine injected before propofol without a tourniquet, cooling or warming the propofol solution, administration through a larger IV catheter size, or changing the speed of injection, did not significantly reduce injection pain. Administration of a small dose of ketamine (0.5 mg/kg) has also been shown to effectively reduce pain associated with administration of propofol.<sup>36</sup>

Relative size of the vein may be important in reducing pain on injection by limiting exposure of the vein to the drug. This is speculated to be the reason that pain is somewhat diminished when propofol is administered through an antecubital vein.<sup>37</sup> A recent study also demonstrated that placing the arm below the heart to induce venous engorgement prior to injection significantly reduced the pain of propofol injection.<sup>38</sup> Pain relief with this method was noted even without lidocaine, but the combination of venous engorgement and administration of lidocaine via modified Bier block was the most effective.

## The Oropharynx and Airway

Topical anesthesia of the oropharynx and upper airway may be used to facilitate upper gastrointestinal endoscopy or bronchoscopy. In these scenarios, topical anesthesia is generally used as an adjunct to procedural sedation as a means to decrease total sedation requirements and blunt adverse responses (eg, laryngospasm) to oropharyngeal stimulation. Three major neural pathways provide sensation to airway structures: trigeminal, glossopharyngeal, and vagus nerves.<sup>39</sup>

Two local anesthetic agents are currently used for topical anesthesia of the oropharynx and upper airway: lidocaine and benzocaine. Although conveniently provided in an aerosolizing container, benzocaine (Cetacaine) must be used with caution in children because of its potential to cause methemoglobinemia.<sup>40,41</sup> With these concerns in mind, lidocaine remains the predominant agent used for topical anesthesia of the oropharynx and

airway. Depending on weight of the patient and volume required, lidocaine can be administered in a concentration ranging from 2% to 4%. When applied to mucous membranes, superficial anesthesia occurs in approximately 1 minute with a peak effect at 3 to 5 minutes. Total doses should not exceed 4 to 5 mg/kg.<sup>42</sup> To increase contact with mucosa, an antisialagogue such as glycopyrrolate may also be administered.

Various alternatives are available to effectively deliver lidocaine to mucosal surfaces. For bronchoscopy, nebulization of lidocaine can easily be achieved using a high-flow nebulization device in the same manner that albuterol is delivered. The technique is easy to use and well tolerated and generally uses equipment that is available in most institutions. For endoscopy and anesthesia of the oral cavity, the local anesthetic agent can be applied directly using a soaked gauze or swab or sprayed directly onto the mucosal surface via a mucosal atomization device or an atomizer. A commercially available disposable pediatric mucosal atomization device (MAD, Teleflex, Research Triangle Park, NC) is available specifically for topical anesthesia prior to bronchoscopy and endoscopy. For topical anesthesia of the distal airway during bronchoscopy, a syringe can also be filled with lidocaine and administered via a small-bore catheter or the working channel of the fiber-optic bronchoscope. Regardless of the technique chosen, total dose of lidocaine must not exceed 4 to 5 mg/kg, as absorption tends to be rapid across mucosal membranes.

## Local Anesthesia Systemic Toxicity: Recognition and Treatment

With the use of local anesthetic agents, the greatest risk of morbidity is the potential for development of toxic plasma concentrations. Local anesthetic-induced systemic toxicity affects the central nervous system (CNS) and CV system. With most local anesthetic agents, CNS toxicity occurs at doses and blood levels below those that produce CV toxicity. Central nervous system toxicity with lidocaine occurs at a plasma concentration of 8 to 10 mg/mL, whereas CV toxicity occurs at a higher plasma concentration of 20 mg/mL.<sup>43</sup> In contrast, the toxic effects of bupivacaine on the CNS and CV system may occur nearly simultaneously at the same plasma level of 3 to 5 µg/mL.

Signs and symptoms of CNS toxicity include light-headedness, dizziness, circumoral numbness, tinnitus, twitching, tremors, and, ultimately, tonic-clonic seizures. With higher doses, CNS excitation including seizure activity is followed by CNS depression, unconsciousness, and respiratory arrest. Blockade of inhibitory pathways in the cerebral cortex yielding to unopposed activity of facilitatory neurons leads to seizure activity.<sup>44</sup> The convulsive threshold of local anesthetic agents and their cardiotoxicity are magnified by hypercapnia and acidosis.<sup>45</sup> Manifestations of CNS toxicity may be blunted or abolished by the concomitant administration of sedative agents. Benzodiazepines, dexmedetomidine, and propofol all mitigate CNS effects of these agents and limit the patient's ability to recognize or report signs of CNS toxicity, thereby resulting in the development of CV toxicity as the first sign of overdose.<sup>46,47</sup>

Death from local anesthetic toxicity is most commonly the result of CV effects of these agents. Local anesthetic toxicity can adversely affect cardiac electrical and mechanical activity in the heart.<sup>48</sup> Bupivacaine may produce severe cardiac dysrhythmias by inhibiting fast sodium and slow calcium channels in the cardiac membrane, resulting in malignant arrhythmias that are resistant to therapy. Local anesthetic agents depress myocardial contractility, with the most potent drugs (ie, bupivacaine and tetracaine) causing the greatest dose-dependent myocardial depression.<sup>49</sup> At toxic plasma concentrations, bupivacaine can cause profound myocardial depression and intractable cardiac arrest. These effects are so profound that resuscitative measures for ventricular tachycardia or fibrillation, including standard Advanced Cardiovascular Life Support (ACLS) protocols, may be ineffective. As it is only the free fraction and not local anesthetic that is bound to plasma proteins that has the potential to cause toxicity, any age- or disease-related process that alters plasma proteins may increase the free fraction and increase risk of toxicity. Infants younger than 6 months have reduced levels of alpha-1-acid glycoprotein, which binds amide local anesthetic agents. Therefore, the free fraction of local anesthetic agents are higher after administration to young infants than older children and adults. The newer local anesthetic, ropivacaine, has vasoconstrictive properties that limits its systemic absorption and increases margin of safety, but cardiac toxicity has been reported after inadvertent intravascular injection and overdose of this agent.<sup>50–52</sup>


Signs and symptoms of local anesthetic CV toxicity include hypertension and tachycardia during the CNS excitation phase, followed by myocardial depression and mild to moderate hypotension, sinus bradycardia, profound

hypotension, ventricular dysrhythmias, and, finally, circulatory collapse. Hypercapnia, acidosis, and hypoxia potentiate the negative chronotropic and inotropic effects of high plasma concentrations of local anesthetic agents. Most local anesthetics have a biphasic effect on the vasculature, producing vasoconstriction at low concentrations and vasodilation at high concentrations.

The primary method of treating toxicity should be avoidance by careful calculation of the dose, use of the lowest necessary dose (concentration and volume), intermittent aspiration to identify vascular penetration, slow incremental injection of the dose, and, when feasible, patient questioning to determine the early CNS signs of toxicity. When used for topical cutaneous and infiltrative purposes, the incidence of local anesthetic toxicity is very low unless there is inadvertent systemic injection or when large doses are administered for extensive procedures, such as repairs of large lacerations. If signs of systemic toxicity occur, CNS manifestations are generally treated with benzodiazepines. Treatment should include standard ACLS protocols with attention to airway and respiratory function to prevent or reverse hypoxemia, hypercapnia, and acidosis. The pharmacologic treatment of arrhythmias and CV depression resulting from LAST is different than other cardiac arrest scenarios, and several practice advisories have been published in the United States and United Kingdom in recent years to alert clinicians to the most effective treatment strategies. The 2012 practice advisory on LAST published by the American Society of Regional Anesthesia and Pain Medicine is the most up-to-date and well researched in the United States. A *Checklist for Treatment of Local Anesthetic Systemic Toxicity* has been developed that summarizes these guidelines; it can be downloaded from [www.asra.com/checklist-for-local-anesthetic-toxicity-treatment-1-18-12.pdf](http://www.asra.com/checklist-for-local-anesthetic-toxicity-treatment-1-18-12.pdf). This checklist can be laminated and included in a local anesthetic toxicity kit or code cart or posted in procedure areas where local anesthetics may be administered. A copy of the checklist can be found in Figure 10-3.

During treatment of LAST, this practice advisory recommends avoiding vasopressin, calcium channel blockers,  $\beta$ -adrenergic antagonists, and local anesthetic agents, as well as reducing the individual epinephrine doses for treatment of hypotension to less than 1  $\mu\text{g}/\text{kg}$ .<sup>53,54</sup> Intra-lipid 20% should be immediately available and administered based on clinical severity and rate of progression of LAST.<sup>55</sup> Although no specific mention is made in the guidelines about use of intra-lipid for the treatment of LAST in children, case

Figure 10-3



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## Checklist for Treatment of Local Anesthetic Systemic Toxicity

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**The Pharmacologic Treatment of Local Anesthetic Systemic Toxicity (LAST) is Different from Other Cardiac Arrest Scenarios**

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- ☐ **Get Help**
- ☐ **Initial Focus**
  - ☐ **Airway management:** ventilate with 100% oxygen
  - ☐ **Seizures uppression:** benzodiazepines are preferred; **AVOID propofol** in patients having signs of cardiovascular instability
  - ☐ **Alert** the nearest facility having **cardiopulmonary bypass** capability
- ☐ **Management of Cardiac Arrhythmias**
  - ☐ **Basic and Advanced Cardiac Life Support (ACLS)** will require adjustment of medications and perhaps prolonged effort
  - ☐ **AVOID** vasopressin, calcium channel blockers, beta blockers, or local anesthetic
  - ☐ **REDUCE** individual epinephrine doses to <1 mcg/kg
- ☐ **Lipid Emulsion (20%) Therapy** (values in parenthesis are for 70kg patient)
  - ☐ **Bolus 1.5 mL/kg** (lean body mass) intravenously over 1 minute (~100mL)
  - ☐ **Continuous infusion 0.25 mL/kg/min** (~18 mL/min; adjust by roller clamp)
  - ☐ Repeat bolus once or twice for persistent cardiovascular collapse
  - ☐ Double the infusion rate to 0.5 mL/kg/min if blood pressure remains low
  - ☐ **Continue infusion** for at least 10 minutes after attaining circulatory stability
  - ☐ Recommended upper limit: Approximately 10 mL/kg lipid emulsion over the first 30 minutes
- ☐ **Post LAST events** at [www.lipidrescue.org](http://www.lipidrescue.org) and report use of lipid to [www.lipidregistry.org](http://www.lipidregistry.org)

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Reprinted from: Neal JM, Mulroy MF, Weinberg GL; American Society of Regional Anesthesia and Pain Medicine. American Society of Regional Anesthesia and Pain Medicine checklist for managing local anesthetic systemic toxicity: 2012 version. *Reg Anesth Pain Med*. 2012;37(1): 16–18, by permission of Wolters Kluwer Health.

reports demonstrating efficacy in infants and children have been reported.<sup>56</sup> Even with all of these measures, local anesthetic toxicity can still be refractory to treatment, and arrangements for extracorporeal membrane oxygenation may need to be rapidly arranged. Prolonged monitoring (>12 hours) is recommended after any signs of systemic local anesthetic toxicity because cardiac depression can persist or recur after treatment.<sup>57</sup>



## Summary

Although procedural sedation can provide significant pain relief for children undergoing invasive procedures, placement of an IV cannula for administration of these agents can still be a source of considerable anxiety and pain, especially for young children. Topical dermal anesthetic agents have been a significant advance in providing better analgesia for these superficial procedures. A number of new formulations and devices have made the provision of cutaneous analgesia quicker and simpler. Local anesthetic agents administered by infiltration or topical application to mucosal surfaces can also provide supplemental analgesia during and after painful procedures, reducing the overall sedative agent requirements. Regardless of the agents used and route of administration, the practitioner must have a thorough understanding of the potential toxicity of these agents, dosing ranges, and current paradigms for treatment of LAST.

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CHAPTER 11

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## **Pediatric Sedation Credentialing and Privileging**

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### **Introduction**



Pediatric procedural sedation is a high-risk clinical activity that remains ubiquitous in any hospital that cares for children. The Joint Commission and the Centers for Medicare & Medicaid Services (CMS) recognize the inherent risk of procedural sedation and require that health care institutions establish sedation practice models that promote patient safety and welfare.<sup>1,2</sup> To maintain accreditation, hospitals are required to comply with The Joint Commission statement on a practitioner's qualifications for conducting sedation: "Individuals administering moderate or deep sedation are qualified and have the appropriate credentials to manage and rescue patients at whatever level of sedation or anesthesia is achieved, either intentionally or unintentionally..."<sup>3</sup> To ensure safe sedation practice, hospitals must have a concise and well-defined process for credentialing and delineating sedation privileges to only those individuals who are qualified.

The role of non-anesthesiology-based practitioners in providing sedation services to children has grown significantly in the past 10 years. Non-anesthesiologists now comprise greater than 80% of sedation practitioners submitting data to the national Pediatric Sedation Research Consortium (PSRC), a collaborative group of institutions that prospectively collects data on pediatric sedation encounters.<sup>4-6</sup> As a whole, these non-anesthesiologist sedation practitioners comprise a diverse group, with varying levels of formal training, education, and experience in procedural sedation.

Pediatric sedation practice standards within institutions are usually developed in accordance with guidelines established by the American Society of Anesthesiologists (ASA), American College of Emergency Physicians (ACEP), American Academy of Pediatrics (AAP), The Joint Commission, and CMS, given their recognized expertise in pediatric sedation.<sup>1,2,7-9</sup> These guidelines are intended to standardize procedural sedation practice and seek to clarify practitioner qualifications for performing sedation. The responsibility of defining and implementing the privileging process rests with individual hospitals and must be “an objective, evidence based process” according to The Joint Commission.<sup>10</sup> Specifications for practitioners include having competency-based training to evaluate patients pre-sedation, perform sedation, monitor patients during sedation, rescue patients who progress to a deeper than planned level of sedation, and recover patients post-sedation.<sup>1,3,7-9</sup> Despite these recommendations, the process used by hospitals for credentialing and privileging sedation practitioners is not uniform.<sup>11-13</sup> Indeed, practitioner qualifications hospitals use for delineating sedation privileges (ie, training, education, and experience) vary considerably between institutions.<sup>11</sup> As a result, with regard to sedation practice, one of the most significant challenges that health care institutions face is establishing a rigorous, consistent process that clearly defines the training, education, and experience that ensures practitioners are competent to perform sedation.

This chapter discusses the medical staff process of granting privileges to licensed independent practitioners and allied health professionals (eg, advanced nurse practitioners, physicians assistants) for performing moderate and deep sedation in children.<sup>1</sup> Minimal sedation is a low-risk clinical activity characteristically not requiring special privileges and will not be discussed in the context of this chapter. Moderate and deep sedation will be referred to collectively as *sedation* or *procedural sedation*, unless otherwise specified. Given the type of procedures and the cognitive state of young children and toddlers, it has become clear that the goal of “moderate sedation” is not feasible, as most patients in this age range require or are sedated to a level consistent with deep sedation. It is also fairly common for practitioners to use the term moderate sedation when they are, in fact, providing deep sedation. Given these issues, we prefer the use of the term *procedural sedation* without an attempt to differentiate different levels of sedation.

The first part of this chapter discusses the general credentialing and privileging process used by health care institutions for medical staff membership and delineation of clinical privileges. Subsequent sections examine competency-based training in procedural sedation as it relates to receiving clinical privileges in pediatric sedation. The first of these sections defines cognitive, psychomotor, and behavioral skills that comprise the foundation for sedation competency, followed by a discussion of specific sedation competencies. The next section examines types of training, education, and experience that institutions require when considering a practitioner's qualifications for sedation privileges. Many institutions adjust privileging for procedural sedation based on training of the practitioner (eg, hospital vs pediatric intensive care unit [ICU] physician vs pediatric anesthesiologist). In such situations, it may be that moderate sedation can be provided by hospitalists, while deep sedation is permitted only by a pediatric ICU physician, pediatric emergency physician, or pediatric anesthesiologist. However, the purpose of this chapter is not to mandate regulation of such practices. Rather, each institution should develop a means to credential and provide appropriate privileging to its medical staff. The methods used by health care institutions to assess sedation skills and competencies are reviewed and followed by a discussion of the focused professional practice evaluation (FPPE) outlined by The Joint Commission. A summary of the credentialing and privileging process is presented in the last section.

## Credentialing and Privileging

*Credentialing* is the process by which hospitals collect and review a practitioner's qualifications for membership to the medical staff and is the initial step in granting clinical privileges. The importance of a hospital's credentialing procedure cannot be overstated, as accreditation and regulatory agencies like The Joint Commission and CMS require that health care organizations have a formal credentialing process.<sup>1,2</sup> The credentialing procedure is typically defined in the institution's medical staff bylaws or some equivalent and clarifies the criteria for membership and clinical privileges based on the practitioner's credentials (eg, practitioner type, current licensure, education and training credentials, board certification).<sup>14</sup> As such, credentialing serves



as the foundation for appointment and prerequisite for granting clinical privileges to health care professionals.<sup>15</sup>

*Privileging* is the process used by health care organizations to grant individual practitioners permission to provide specific clinical services and perform certain procedures. Criteria for granting initial privileges in a specific area of practice are based on the practitioner's level of competency in these areas. At a minimum, a hospital considers the individual's formal training, education, and experience before determining competency and granting privileges. Appropriate delineation of privileges based on a practitioner's competency is one of the most important functions an institution can perform to promote patient safety. Institutions are responsible for defining qualifications and assessing methods used to determine whether an individual is competent to perform his or her assigned tasks or requested procedures. The Joint Commission and CMS require hospitals to have a formal process that is objective and evidence based in granting and assessing privileges.<sup>1,2</sup> The 2013 Joint Commission standards state: "The hospital defines the competencies it requires of its staff who provide patient care, treatment, or services."<sup>16</sup> The Joint Commission further qualifies that the "hospital uses assessment methods to determine the individual's competence in the skills being assessed."<sup>17</sup>

While health care institutions may use any of a number of methods for defining a practitioner's qualifications and delineating clinical privileges, the *core privileging* approach has become one of the most common and preferred methods.<sup>15</sup> Core privileging is the process in which a core set of privileges are granted to an individual practitioner, who is deemed qualified to perform these duties based on successful completion of a residency or fellowship in a particular specialty. For example, physicians who have completed a fellowship in pediatric critical care medicine (PCCM) will automatically have core privileges in a number of clinical activities and procedures performed in the ICU, including care of any child with a life-threatening illness, initiation and management of mechanical ventilation, and placement of central venous catheters.

Practitioners may also request special privileges for performing specific procedures or clinical activities that are not included in their core privileges. Procedures and services in this category were often not part of the formal educational curriculum in the individual's residency or fellowship training program. Specific privileges outside the core privileges are frequently considered more specialized and higher risk and require additional education,

training, or experience. Moderate and deep sedation privileges often fall in this category. Whether or not an institution uses the core privileging process, delineation of moderate and deep sedation (procedural sedation) privileges may require supplementary documentation of sedation expertise and additional training and experience in sedation.

## Defining Sedation Skills and Core Sedation Competencies

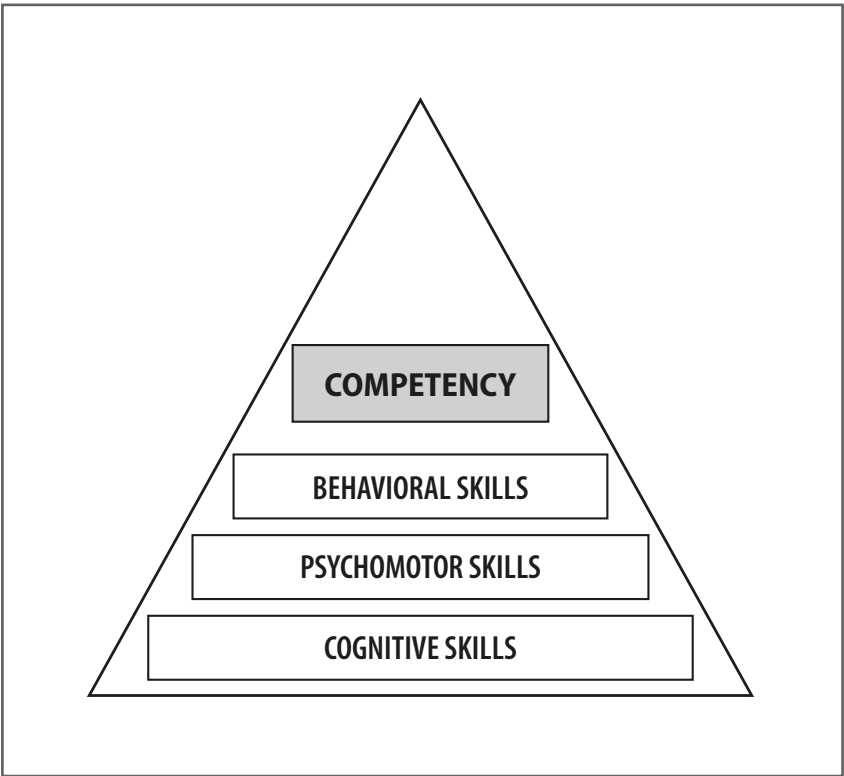
There is no uniform definition specifying what constitutes medical competency that includes all of the varying dimensions of clinical practice.<sup>18</sup> One commonly used definition defines medical competency as the integration of a practitioner's cognitive, psychomotor, and affective skills to achieve a desired outcome.<sup>19</sup> Cognitive skills comprise intellectual abilities ranging from recalling facts and comprehending information to complex problem-solving.<sup>20</sup> Intellectual skills provide the basis for developing a practitioner's psychomotor and affective (behavioral) abilities. Psychomotor abilities encompass the motor-skill aspects of clinical practice and include the spectrum from having the ability to conduct a simple procedure to performing complex tasks under diverse situations. The affective aspect of clinical practice concerns a practitioner's behavior and is often considered the most difficult quality to assess. The ability to effectively listen, communicate, and collaborate with medical staff, patients, and families is an example of affective skills. The importance of affective skills like communication cannot be overstated, as the majority of serious medical errors reported to The Joint Commission can be attributed to breakdowns in communication among team members.<sup>21</sup> Finally, competency is also context dependent in that it relates an individual's ability to skillfully perform a procedure or clinical activity for a specific patient population within a particular field, situation, or setting.<sup>18,22–24</sup> The Joint Commission reinforces this point: "When a hospital defines specific competencies, it should consider the needs of its patient population, the types of procedures conducted, conditions or diseases treated, and the kinds of equipment it uses."<sup>25</sup> To say a practitioner is competent to perform procedural sedation means the practitioner is able to integrate his or her cognitive, psychomotor, and behavioral skills to safely and effectively deliver sedation within the environment in which he

or she works. Together, these aspects of sedation practice are the foundation for achieving competencies in sedation (Figure 11-1) and are discussed in greater detail in the following section.

### Cognitive, Psychomotor, and Behavioral Skills in Sedation: The Foundation for Sedation Competency

Safe and effective pediatric procedural sedation requires incorporation of a number of cognitive, psychomotor, and behavioral skills. The sentinel reports by Cotè et al describing systems-related sedation complications and data from actual sedation events from the PSRC provide concrete information on the types of skills needed by the sedation practitioner to effectively perform sedation.<sup>4–6,26–28</sup> In the report of Cotè et al, the critical incident analysis of 95 severe sedation-related adverse events reported to the US Food and Drug

Figure 11-1



The foundation for competency: cognitive, psychomotor, and behavioral skills

Administration and the US Pharmacopeia Convention shed light on the relationship between practitioner performance and sedation outcomes.<sup>26,27</sup>

Poor outcomes, including permanent neurologic injury or death, were linked to insufficient practitioner knowledge, technical skills, and (behavior) vigilance relevant to performing safe and effective procedural sedation. Specific areas of deficiency included inadequate performance of a pre-sedation risk assessment, lack of knowledge of sedative drug pharmacology and dosing, incomplete understanding and use of sedation monitoring, lack of appropriate response to monitoring information, and insufficient recovery and discharge procedures. In a number of cases, inadequate practitioner assessment of sedation depth and insufficient resuscitation skills (failure to rescue) likely contributed to poor outcomes, particularly when sedation occurred in a nonhospital-based venue.<sup>26</sup> Respiratory compromise was the initial event in greater than 80% of the cases. This finding underscores the importance of understanding a sedative drug's effect on upper airway tone and respiratory drive and being able to interpret information from direct patient observation as well as monitoring equipment (ie, pulse oximetry and capnography).

The PSRC represents a large-scale national database of approximately 30 sedation programs in the United States in which tens of thousands of actual sedation encounters are recorded. Published data from the PSRC clarify the most common serious sedation-related complications and the psychomotor and behavioral skills required to manage these events.<sup>4,5,28</sup> While serious sedation-related complications were rare, adverse sedation-related events that had potential to progress to a life-threatening complication were not uncommon, particularly when propofol was used as the primary sedative.<sup>4</sup> The most common sedation-related adverse events included oxygen desaturation (<90%), upper airway obstruction, apnea, coughing, airway secretions, and laryngospasm.<sup>4,5,28</sup> Respiratory intervention skills required during sedation were also not uncommon and included administration of oxygen; repositioning of the airway; performance of a jaw thrust; bag-mask ventilation; suctioning; placement of an oral, nasopharyngeal, or laryngeal mask airway; and endotracheal tube intubation. Overall, when propofol was compared with other sedatives, airway interventions were significantly more common, highlighting the greater level of skill required for conducting deep sedation with propofol.<sup>5</sup>

The reports by Cotè et al, data from the PSRC, and guidelines and statements from several professional organizations, including the ASA, AAP, ACEP, and National Institute for Health and Care Excellence, specify the necessary prerequisite cognitive, psychomotor, and affective skills required to competently perform sedation.<sup>7,9,29–34</sup> Of note, higher levels of skill and vigilance are required for practitioners performing deep sedation with any of the agents discussed in this manual, including propofol.<sup>31</sup> Box 11-1 summarizes what are considered the most important cognitive and intellectual skills required for performing sedation. In addition, technical and behavioral skills necessary for sedation competency are listed in Box 11-2. All practitioners requesting moderate or deep sedation privileges should, at a minimum, receive education, training, or experience in these areas.

## Core Sedation Competencies

*Clinical competency* can be defined as the ability of a practitioner to apply his or her cognitive, psychomotor, and behavioral skills to a particular clinical task or activity and achieve the desired outcome.<sup>19</sup> Procedural sedation is a complex, multifaceted clinical activity of varying degrees with different components that require diverse skills and competencies. For example, a number of skills required to competently perform a pre-sedation risk assessment (eg, history taking, physical examination skills) are different than those needed to manage the patient with sedation-related upper airway obstruction (eg, communication, leadership [teamwork] skills). Similarly, higher levels of resuscitative skills are required for performing deep sedation compared with moderate sedation. Thus, to say a practitioner has the competencies to perform procedural sedation means that the practitioner is able to apply and integrate the necessary cognitive, psychomotor, and behavioral skills to all aspects of the sedation encounter within the context of his or her practice. As such, sedation competency requires the practitioner to perform a number of distinct tasks proficiently throughout the entire sedation process.

The Joint Commission requires hospitals to define the competencies of its practitioners who provide patient care.<sup>16</sup> Published sedation guidelines from the AAP, ACEP, ASA, and Joint Commission describe the general competencies required by sedation practitioners to safely and effectively conduct procedural sedation.<sup>1,7–9</sup> In general, these guidelines specify that sedation practitioners have the following competencies:

**Box 11-1. Cognitive Skills for Sedation Competencies****Cognitive Skills  
(Knowledge and Intellectual Abilities)****Practitioners must be able to**

- Apply a systematic approach for performing procedural sedation that takes into account the characteristics of the patient, procedure, and sedative drug options.
- Describe the effects of sedative drugs on upper airway tone and respiratory drive.
- Identify pre-sedation risk factors by history and physical examination that predispose the patient to sedation-related complications, eg, obstructive sleep apnea, anatomic airway abnormalities, tonsillar hypertrophy, American Society of Anesthesiologists (ASA) classification.
- Describe the pre-sedation preparation process provided to patients and caregivers, which includes information about objectives of sedation, anticipated changes in behavior following sedation, and sedation risks, benefits, and alternatives.
- Explain the informed consent and time-out process.
- List the monitoring and resuscitation equipment required for conducting sedation.
- Demonstrate in-depth knowledge of the pharmacology, clinical indications, dosing, and drug interactions of common sedative drugs and their antagonists.
- State fasting guidelines based on age for liquids and solids.
- Explain principles, indications, and use of the following cardiorespiratory monitoring tools used during sedation: blood pressure, electrocardiograph, pulse oximetry, capnography, pretracheal stethoscope.
- Interpret information derived from pulse oximetry (oxygen saturation) and capnography (carbon dioxide values and waveforms).
- Recognize the adequacy of oxygenation and ventilation by direct observation and respiratory monitoring.
- Define minimal sedation, moderate sedation, deep sedation, and general anesthesia as defined by the ASA and American Academy of Pediatrics.
- List the most common serious sedation-related adverse events: oxygen desaturation, upper airway obstruction, apnea, coughing, secretions, and laryngospasm.
- Specify the most common respiratory maneuvers that may be required during sedation: administration of oxygen; repositioning of airway; performance of jaw thrust; bag-mask ventilation; suctioning; placement of an oral, nasopharyngeal, or laryngeal mask airway; and endotracheal tube intubation.
- Explain the concept of *rescue* from a deeper than planned level of sedation.
- Describe the roles of personnel and list equipment required in the post-sedation recovery environment.
- Know post-sedation recovery phases and monitoring requirements.
- Clarify post-sedation discharge criteria.

Box 11-2. Psychomotor and Affective Skills for Sedation Competencies
<b>Psychomotor Skills</b> (Motor [Technical] Abilities)
<b>Practitioners must be able to</b>
<ul style="list-style-type: none"><li>• Set up age- and size-appropriate monitoring and resuscitation equipment.</li><li>• Apply and troubleshoot monitoring equipment, including pulse oximetry and capnography.</li><li>• Administer oxygen via mask or nasal cannula.</li><li>• Conduct oropharyngeal suctioning.</li><li>• Perform basic airway skills: airway repositioning, chin lift, jaw thrust maneuvers.</li><li>• Apply continuous positive airway pressure.</li><li>• Perform bag-valve-mask ventilation.</li><li>• Place oropharyngeal, nasopharyngeal, and laryngeal mask airways.</li><li>• Perform endotracheal tube placement.</li><li>• Conduct cardiopulmonary resuscitation.</li></ul>
<b>Affective Skills</b> (Attitudes and Behavioral Abilities)
<b>Practitioners must be able to</b>
<ul style="list-style-type: none"><li>• Listen and communicate effectively with patients and family members.</li><li>• Communicate and collaborate well with sedation team members.</li><li>• Promote effective closed-looped communication among sedation team members.</li><li>• Work effectively as a team member.</li><li>• Be attentive to changes in patient’s medical condition.</li><li>• Lead resuscitative efforts in the event of respiratory or cardiovascular instability.</li></ul>

1. Performance of a pre-sedation risk assessment
2. Administration of sedative drugs and their antagonists
3. Evaluation and monitoring of the sedated patient
4. Recognition and management of sedation-related complications
5. Recovery and discharge of patients following sedation

Within these guidelines, the concept of *rescue* is highlighted. The Joint Commission specifies that practitioners must be able to “rescue patients at whatever level of sedation or anesthesia is achieved.”<sup>3</sup> Practitioners conducting moderate sedation must be competent to recognize and manage a compromised airway and inadequate oxygenation and ventilation. Practitioners planning to perform deep sedation must be additionally competent to manage an unstable cardiovascular system. Box 11-3 lists the core sedation

competencies compiled from the ASA, AAP, ACEP, Joint Commission, and CMS. The requirements (ie, training, education, and experience) institutions use to qualify an individual for sedation privileges are discussed in the next section. It should also be recognized that as the border between moderate and deep sedation cannot be adequately separated based on medications used, type of procedure, or patient status, differential qualifications for privileges of these 2 planes of sedation are not recommended. It is suggested by the author that those desiring to perform moderate or deep sedation should be credentialed under the term *procedural sedation*, which includes assurance of competency to perform the tasks outlined for deep sedation. However, it is recognized that some institutions may choose to separate these 2 categories

### Box 11-3. Pediatric Sedation Core Competencies

#### Within the context of his or her practice, the sedation practitioner will

##### Pre-sedation

- **Perform a focused pre-sedation health history and physical examination** that accurately and efficiently identifies medical conditions that predispose the patient to greater sedation risk.
- **Counsel and prepare patients and/or legal guardians** such that they are satisfied with the information and well informed as to the anticipated effects, risks, and benefits of sedation and alternatives to sedation (informed consent).
- **Engage and prepare sedation team members for sedation** that effectively communicates the sedation plan (time-out) and individual roles.

##### During Sedation

- **Administer and titrate sedative drugs** in a safe and effective manner that achieves the desired clinical effect.
- **Assess the depth of sedation accurately and attentively** that promotes a rapid response to changes in sedation depth.
- **Monitor the patient's respiratory and cardiovascular condition diligently** such that changes in oxygenation, ventilation, and cardiovascular status are immediately recognized and responded to in a manner that enhances the effectiveness of treatment measures.
- **Treat the previous conditions proficiently** such that the chances of the event progressing to a severe sedation-related complication are reduced.
- **Rescue** patients who progress to a deeper than planned level of sedation.

##### Post-sedation

- **Recover patients post-sedation attentively and systematically** in a structured environment that promotes patient (family) safety and well-being.
- **Educate and support patients (and families) on discharge** such that they are well informed and highly satisfied.



based on training of the physician. In this scenario, while all competency in specific tasks required of the sedation practitioner may be the same, medications that generally result in deep sedation (ie, propofol or ketamine) are restricted to specifically trained physicians such as pediatric emergency physicians, pediatric ICU physicians, and pediatric anesthesiologists.

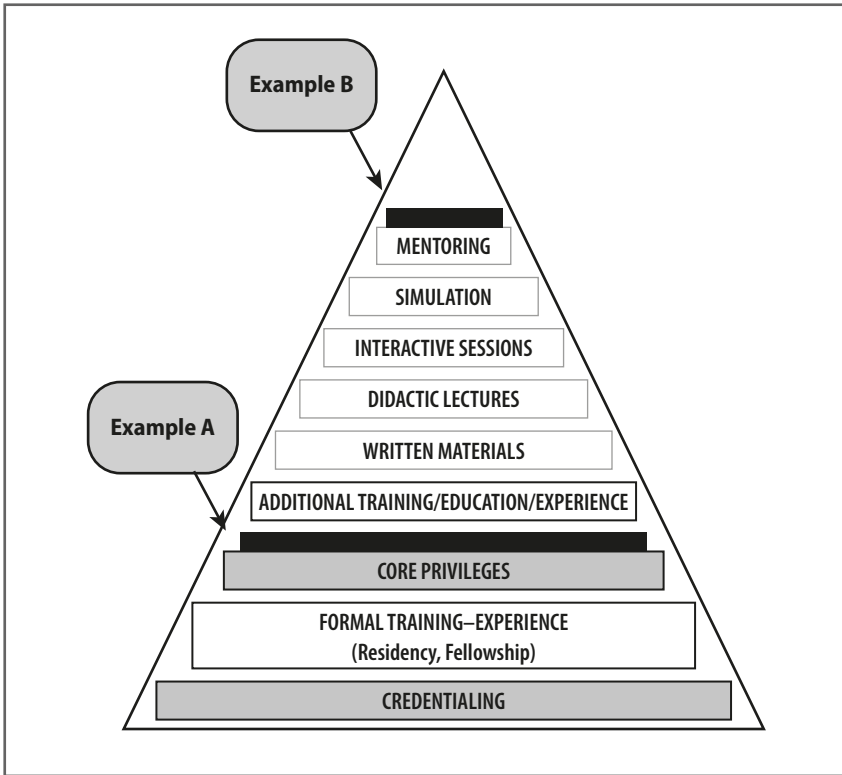
## Achieving Sedation Skills and Core Sedation Competencies

Attaining sedation competency requires training, education, and experience in the field of pediatric sedation. Thresholds for the amount and type of training and experience a practitioner requires to qualify for procedural sedation privileges will vary among hospitals (Figure 11-2). For some situations, requirements for sedation privileges may be included as part of core privileges, based on successful completion of a pediatric subspecialty in which formal sedation training is part of the educational curriculum (eg, pediatric emergency medicine [PEM], PCCM; see Figure 11-2, example A). Some institutions will also continue to distinguish qualification requirements between moderate and deep sedation. For example moderate sedation may be part of a practitioner's core privileges (Figure 11-2, example A), whereas additional training and experience may be required for deep sedation privileges (Figure 11-2, example B). Turmelle et al describe a staged 3-tiered training program for pediatric hospitalists in which privileges for propofol sedation required the highest level of training (tier 3).<sup>35</sup> Deep sedation privileges may also be restricted to a specific group of physicians. When sedation, moderate or deep, is not part of an individual's formal training program, most institutions will require additional experience, training, and education to receive sedation privileges (Figure 11-2, example B). The next section is a discussion of different types of training, education, and experience that institutions will consider to determine whether a practitioner has the qualifications to be granted sedation privileges.

### Formal Training and Education (Residency or Fellowship)

Several pediatric specialties outside of anesthesiology have assumed a greater role in providing sedation services due to formal training and exposure to sedation, a relative shortage of pediatric anesthesiologists,

Figure 11-2



Institutional requirements for delineating sedation privileges. Credentialing is a prerequisite for core and sedation privileges. Formal training in a particular field (eg, pediatric emergency medicine) may be sufficient in some cases to grant sedation privileges (eg, moderate sedation) (example A). When formal training is insufficient, additional training and education are required (example B) and may include one or more of the following: written materials, lectures, interactive sessions, medical simulation, and mentoring.

and the fact that pediatric sedation is often an integral part of their practice.<sup>36</sup> Pediatric critical care medicine physicians, PEM physicians, and, more recently, pediatric hospital medicine (PHM) physicians comprise the 3 largest non-anesthesiologist-based pediatric subspecialties performing procedural sedation in children.

Pediatric procedural sedation is a fundamental part of PEM and PCCM practice. Pediatric critical care medicine and PEM physicians also receive a significant amount of education and experience in sedation as part of their fellowship training. Indeed, sedation education is a formal part of the

educational curriculum in PEM and PCCM fellowships.<sup>33,37,38</sup> Following completion of fellowship, PEM and PCCM physicians are expected to be proficient in providing sedation. In addition, PEM and PCCM fellows receive formal training and experience in cardiorespiratory monitoring, advanced airway management, and cardiopulmonary resuscitation, as well as cognitive and psychomotor skills directly applicable to sedation practice. By virtue of their training and experience, PEM and PCCM physicians are often well suited for receiving moderate sedation privileges as part of their core privileges and deep sedation privileges with some additional training and experience. Indeed, a number of very successful sedation services are based out of pediatric emergency or critical care medicine programs.<sup>28,39</sup>

Pediatric hospital medicine physicians have assumed a greater role in some institutions in providing pediatric sedation due to their role in caring for children within a hospital setting, involvement they have in children receiving procedural sedation, and understanding they have of hospital functions. Turmelle et al described the successful development of a PHM-based sedation program with anesthesiology collaboration following implementation of a staged “3-tiered sedation training” program.<sup>35</sup> Pediatric hospital medicine physicians requesting propofol privileges were required to have the highest level of training, tier 3, which consisted of anesthesia experience in the operating room and 25 supervised propofol sedations. With pediatric anesthesiology oversight, this same group described successful use of propofol by PHM physicians for pediatric procedural sedation.<sup>40</sup> While PHM physicians do not receive formal training in procedural sedation, recent development of PHM core competencies specifically addresses the core knowledge, skills, and behaviors needed for the hospitalist to perform procedural sedation.<sup>41</sup> Depending on the institution, various other pediatric subspecialties (eg, pediatric hematologists performing moderate sedation for invasive oncology procedures) may receive privileges in performing sedation (usually moderate) and often for a specific patient population.

## **Additional Training, Education, and Experience**

Additional training, education, and experience are required when an individual’s formal training and experience do not meet threshold criteria for receiving sedation privileges at a hospital. This section describes methods used by hospitals to provide additional training to ensure that practitioners

requesting sedation privileges are qualified. While each of the educational and training approaches described herein has its advantages and disadvantages, a couple of generalizations can be made. Interactive teaching approaches (eg, case discussions, simulation) are superior to passive educational techniques (eg, didactic lectures) in changing physician behavior and performance.<sup>42</sup> Multiple instructional techniques are superior to any one single educational format.<sup>43</sup> Educational methods including simulation complement but do not substitute for education and training that occurs during patient care (eg, mentoring).<sup>44</sup>

### *Didactic Written Materials and Lectures*

Written materials and lectures provide the learner with cognitive knowledge (eg, factual information). Written materials (eg, articles, manuals, policies) have the advantage of presenting a large amount of factual information in print or online to the learner at a pace determined by the student.<sup>45</sup> Virtually all instruction in sedation that has been published has written materials that discuss, at a minimum, pre-sedation risk assessment, fasting guidelines, definitions of sedation levels, pharmacology of sedative drugs, sedation monitoring, sedation-related complications and their management, and post-sedation recovery and discharge criteria.<sup>46–50</sup>

Didactic lectures have the advantage of being able to deliver a large amount of cognitive information to the student while having the flexibility to also emphasize a particular area. Lectures are often “coned-down” versions of the written material, reflecting what the instructor considers the most important pieces of information. Lectures may be delivered by a variety of media types (eg, live, audio, online), with the amount and pace determined by the instructor.<sup>45</sup> Like written materials, didactic lectures are primarily passive methods of teaching and have been found to have a limited role in actually changing physician attitudes and performance.<sup>42</sup> Lectures are also one of the most common methods used to teach sedation and may include the pre-sedation risk assessment, pharmacology of sedative drugs, sedation monitoring, sedation-related adverse events, and post-sedation recovery.<sup>49</sup> Such didactic courses are followed by formal testing using standardized multiple-choice tests to demonstrate acquisition and retention of an acceptable knowledge base.

### *Interactive Small Group Sessions*

Teaching that uses interactive approaches is more effective than written material and didactic lectures in improving physician knowledge and behavior.<sup>42</sup> Small group case- and problem-based discussions and scenarios are one example; they deal with higher orders of cognitive skills, including comprehension, reasoning, and evaluation. Hands-on sessions are also interactive in nature and are particularly effective in teaching motor skills (eg, airway repositioning maneuvers, bag-mask ventilation). Interactive sessions often include formative assessments and feedback from instructors that can promote reflection and more effective learning strategies. The Pediatric Advanced Life Support (PALS) Course is a good example of interactive instruction that employs instructor feedback and is often a requirement for being granted sedation privileges. These should be standard PALS courses including not only a didactic portion but a hands-on skills component as required by the American Heart Association. The PALS Course uses interactive case-based scenarios that require students to use their cognitive, psychomotor, and behavioral skills to effectively manage a variety of resuscitation-based situations.<sup>51</sup> Hands-on interactive sessions can enhance use and understanding of monitoring (eg, capnography) in a case-based learning environment.<sup>50</sup>

### *Medical Simulation*

McGaghie et al define medical simulation as “a person, device, or set of conditions which attempts to present [education and] evaluation problems authentically.”<sup>44</sup> Various forms of simulation exist and include partial task simulation, primarily used to teach a specific task or procedure (eg, intubation heads); standardized patients (eg, objective structured clinical examinations); and full human patient simulations that use life-sized manikins with physiological response capabilities (high fidelity).<sup>23,45</sup> High-fidelity simulation manikins are particularly effective in teaching case- and problem-based scenarios that require integration of higher cognitive functioning (eg, clinical decision-making), technical abilities, and behavioral performance (eg, teamwork).<sup>21,23</sup> For the purposes of this section, *simulation* will refer to full human patient simulation.

Medical simulation was developed as a response to the observation that centers with higher volumes of a given condition typically have better outcomes for that disorder (the so-called “volume-outcome” relationship).<sup>52–54</sup>

By enabling standardized reproduction of rare events, it was hoped that outcomes for those events could be improved. Numerous studies have since confirmed this, and the value of medical simulation is now widely recognized; indeed, it has even become the standard method of education in a number of fields.<sup>55-61</sup> The benefit of medical simulation derives from its relationship with adult education, which specifies a cycle or hierarchy of education that proceeds from the acquisition of knowledge through its initial practice in some external environment and onward through the attainment of competency.<sup>62</sup> By providing a safe and standardized environment in which to practice, simulation can therefore facilitate necessary transitions between knowledge and skill that must occur if a clinician is to become competent at an activity.

A number of studies show that medical simulation is effective for teaching health care professionals communication, psychomotor skills, and important attributes for performing procedural sedation.<sup>21,23,44</sup> Of note is the important role human simulation has in teaching the affective aspects of medical care that shape teamwork, including adaptive behaviors, leadership skills, and closed-loop communication.<sup>21</sup> Simulation is a valuable educational tool in teaching cognitive, motor, and behavioral sedation skills to health care personnel.<sup>63</sup> Simulation has been found to be particularly effective in teaching sedation skills to nurses, pinpointing personnel and system limitations in promoting sedation safety, demonstrating to practitioners the shortcomings of pulse oximetry monitoring in sedated patients receiving supplemental oxygen, and enhancing physician performance during sedation.<sup>64-67</sup> Shavit et al evaluated the effects of physicians completing a simulation-based sedation course on actual clinical performance and compared them with physicians who had not taken the course.<sup>67</sup> The 2 groups were contrasted using a safety evaluation tool that assessed physician behavior before, during, and after procedural sedation. Significant differences were found between the 2 groups in terms of behaviors that promote patient safety.

Several courses have now been developed that integrate didactic teaching with simulation.<sup>49,66-68</sup> Recognizing the importance of multiple teaching methods, the Society for Pediatric Sedation created a sedation practitioner course that consists of a course syllabus, didactic lectures, small group interactive sessions, and high-fidelity simulations.<sup>49,69</sup> Simulations comprise the bulk of the course (approximately 60%) and consist of skill-based sessions and core case scenarios. Skill-based simulation sessions are designed

to instruct students in recognition and management of sedation-related adverse events, while core case scenarios involve common case scenarios and require students to role-play and work as a team. Student satisfaction for simulation-based courses is typically very high, with the vast majority of students stating that simulation is the most valuable part of the course, particularly for practitioners with less sedation experience.<sup>49</sup> Although there remains limited evidence-based medicine, many practitioners and authorities on the subject believe that human simulation is the most effective technique available outside the natural environment to teach the necessary skills to competently perform procedural sedation.

### *Clinical Experience and Mentoring*

In theory, educational methods should precede or coincide with education that involves direct patient care. Numbers and types of procedural sedations performed are frequently used by hospitals as one of the requirements for granting privileges to practitioners. The basis for using experience as a requirement stems from findings in other fields that demonstrate caring for a larger number of patients or performing a greater number of procedures is associated with better outcomes.<sup>14</sup> In addition, higher clinical activity in a particular area like sedation may also be accompanied by improvements in overall team performance. This may be particularly relevant for more senior procedural sedation practitioners when they move to a new institution. In such cases, it may be appropriate to ask for a list of procedure logs demonstrating the patient's demographics (eg, age, weight), type of procedure, and agents used.

When coupled to a supervising mentor, clinical experience provides the practitioner with the best overall educational environment in which to learn sedation. It provides the practitioner a real-life, hands-on experience that incorporates higher educational cognitive, psychomotor, and behavioral skills needed to achieve sedation competencies.<sup>45</sup> Mentoring is a particularly effective educational tool in that it is interactive and facilitates instructor feedback and assessment of skills. Direct observation by a supervising physician also promotes patient safety in that the more experienced clinician can intervene if safety issues arise. While mentoring has a number of advantages, the truth is that it is difficult to do. Physician (mentor) time constraints, choice of mentor, and practice variations among observing physicians all contribute to making the supervisory process difficult.<sup>14</sup> Thus,

as an educational tool, direct observation may be best reserved for the end of a practitioner's training for a finite number of supervised sedations as well as for performance and outcome evaluations.<sup>35</sup>

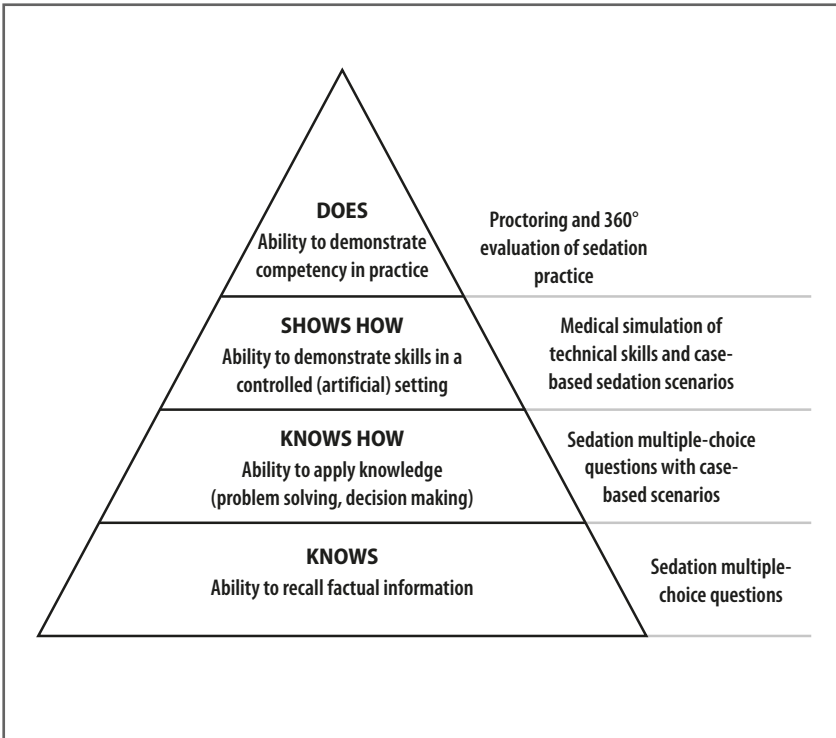
## Assessing Sedation Competencies

Assessment is an important component of competency-based medical education and a critical piece in determining if an individual has the qualifications to be granted specific privileges. The Joint Commission emphasizes this point: "The hospital uses assessment methods to determine the individual's competence in the skills being assessed. Note: Methods may include test taking, return demonstration, or the use of simulation."<sup>17</sup> Most assessment processes used for privileging are summative in nature in that they evaluate the practitioner's ability to competently perform specific procedures or clinical activities.<sup>23</sup> Performance assessment tools should be reproducible and consistent (reliable) and test the intended skill or competency (validity).<sup>70</sup> Due to the complex, multifaceted nature of clinical practice, more than one assessment method should be used to assess medical competence. In addition, The Joint Commission requires that "an individual with the educational background, experience, or knowledge related to the skills being reviewed assesses competence."<sup>71</sup>

The competence pyramid introduced by Miller describes assessment of clinical performance at 4 levels. The base of the pyramid, *knows*, is the lowest level (level 1) of assessment and deals with testing factual knowledge (eg, written examinations); it is followed by *knows how*, or the ability to apply knowledge in solving problems.<sup>62</sup> Assessment at higher levels of performance, or *shows how*, includes testing of cognitive, psychomotor, and behavioral skills in a controlled setting (eg, full human simulation). While knowledge and the ability to apply and demonstrate intellect in an artificial setting are important components of training and assessment, they do not guarantee competent performance in real life. The tip of the pyramid, *does*, assesses actual clinical performance by a qualified instructor (proctor) in the setting in which the practitioner works and is the framework in which competency is determined. Figure 11-3 describes the hierarchical framework for clinical assessment and its application to assessment of sedation knowledge,



Figure 11-3



Application of Miller's hierarchy of clinical competence to competency-based sedation assessment.

Adapted from: Wass V, Van der Vleuten C, Shatzer J, Jones R. Assessment of clinical competence. *Lancet*. 2001;357(9260):945–949, by permission of Elsevier.

skills, and competencies. The following discussion describes the most common methods of assessing knowledge, skills, and competency in sedation.

## Written Examinations

Multiple-choice questions are the most common written tests used to assess factual knowledge (knows) and clinical reasoning and decision-making (knows how).<sup>18,22,23,62,70</sup> Multiple-choice questions designed to test recall of factual information are efficient to conduct, easily graded, and highly reliable. More difficult is designing multiple-choice questions that assess higher intellectual skills of comprehension, clinical reasoning, and problem-solving

(Miller level 2).<sup>18,22,23,62,70</sup> Written examinations can be designed to test higher levels of cognition by presentation of a clinical scenario followed by a sequence of questions aimed to assess clinical judgment and reasoning. Multiple-choice tests are frequently used to assess cognitive skills in sedation by establishing a minimum score for passing.<sup>49</sup> However, written tests may seem unnatural and too far removed from clinical practice.<sup>19</sup> They also do not test psychomotor skills needed for sedation and have difficulty assessing the important attitudinal attributes like communication and teamwork.<sup>22,23</sup> Additionally, very few written tests offered by individual institutions have undergone any analysis for content or validity of the questions. Thus, additional testing methods should be used to better assess and predict how well a practitioner will perform during an actual patient encounter.

## Medical Simulation

Medical simulation has a number of advantages as a tool to assess a practitioner's cognitive, technical, and behavioral skills. Simulation promotes a reproducible realistic environment that can be tailored to assess specific educational objectives. Simulation testing can be designed to target specific performance measures that occur in real-life clinical situations (eg, airway repositioning maneuvers in response to upper airway obstruction, identifying cause of hypoxemia). Simulation is particularly valuable in assessing performance for uncommon events that may not be witnessed during the proctoring process. Case- and problem-based medical simulation is particularly useful in assessing higher-level intellectual functioning (eg, analysis, problem-solving, decision-making) as well as procedural skills (eg, bag-mask ventilation). Medical simulation also is a powerful tool to assess affective functions, including communication with patients and families, teamwork, and collaboration with other health care professionals.<sup>23,65</sup> Using a checklist format, instructors can assess student performance in specific case scenarios (eg, sedation-related upper airway obstruction) in specific areas of cognitive function (eg, recognition of upper airway obstruction) and motor skills (airway repositioning).<sup>49</sup> Blike et al used medical simulation to assess personnel and system performance in rescuing patients from sedation-related complications.<sup>65</sup>

## Direct Assessments of Clinical Practice: Proctoring and Multisource Evaluations

### *Proctoring*

Proctoring assesses a practitioner's performance under real-life circumstances and usually involves a defined period or set number of cases. Observation and evaluation by a qualified practitioner allows direct assessment of performance during all phases and aspects of the sedation encounter. Performance measures that are difficult to assess with other evaluative tools (eg, interactions with patients and families, communication with medical staff, working as a team member) are particularly amenable to the proctoring process.<sup>23</sup> Proctoring can also be interactive and formative and provide learners with valuable feedback that enhances learning. Structured practitioner assessments using checklists by a supervising physician can have the same degree of reliability as standardized patients. Difficulties with proctoring include the subjective nature of the process if not structured, practice variability among supervising physicians, and the inability to reproduce clinical scenarios that the proctor may want to assess.

Several institutions have described supervised performance of a set number of procedures (eg, 25 propofol sedations) as part of their training process.<sup>35</sup> There are a number of reasons why procedural sedation performance is particularly amenable to proctoring. Procedural sedation is a finite clinical activity of discrete phases (ie, pre-sedation, sedation, and post-sedation) that can be assessed individually or as a whole. Consequently, the time commitment for a proctor can be relatively well defined. Procedural sedation also has specific areas of competency that can be evaluated that are common to all sedation encounters (eg, performance of a pre-sedation risk assessment). Proctoring a practitioner's performance in sedation has its limitations, similar to direct observation in training. A supervising physician may not witness a practitioner's response to an uncommon sedation-related event (eg, laryngospasm) due to the infrequency in which these events occur. Proctoring also requires a time commitment from supervising physicians.

### *Multisource (360-Degree) Evaluations*

Assessments by members of the clinical team (eg, sedation nursing staff), colleagues, and patients and families can provide valuable information about a practitioner's interpersonal skills, ability to work as a team member, and

overall professional behavior.<sup>23</sup> While not routinely used as an assessment tool in sedation performance, it has great potential to provide types of information not readily assessable through other evaluative methods. In particular, it gives an indication of how well the practitioner will perform with other health care professionals within the environment in which they will work.

## **Focused Professional Practice Evaluation and Re-privileging**

Initial specific privileges are, in reality, provisional and require institutions to have a procedure in place that monitors the practitioner's performance over a specified period. The FPPE is a process established by The Joint Commission that requires institutions to ensure that a new practitioner (or an existing practitioner requesting new privileges) is competently performing the procedure or clinical activity he or she had been privileged for.<sup>14</sup> According to The Joint Commission, the FPPE "is a time-limited period during which the organization evaluates and determines the practitioner's professional performance."<sup>72</sup> The assessment process is defined by the institution and may include any number of mechanisms, including chart review, performance of a certain number of procedures, proctoring, peer review, and multisource evaluations.<sup>72</sup> The FPPE process typically includes all privileges, sedation included, and therefore will reflect a practitioner's overall clinical performance within an institution. Renewal of privileges occurs every 2 years and, like initial privileges, requirements will vary among hospitals. Some form of quality measure is often used and may include documentation of a minimum number of sedations and outcome data, including incidence of critical adverse events.

## **Summary**

Procedural sedation in children is a complex, high-risk clinical activity. Institutions must have a formal, evidence-based credentialing and privileging process that ensures only individuals who are qualified to administer sedation are allowed to do so. Individual institutions are responsible for

defining the qualification requirements for a practitioner to be eligible to receive procedural sedation privileges. Formal training and experience provides the foundation for a practitioner's qualifications and alone may or may not be sufficient for these privileges. When an institution deems an individual's formal training as insufficient, a number of methods are available to provide additional training, education, and experience. Multiple educational techniques are superior to any one approach and must be followed by one or more evaluative methods to assess performance. Outside the clinical setting, medical simulation is the most comprehensive method to teach the necessary cognitive, psychomotor, and behavioral skills to competently perform sedation. Ideally, some level of training and performance assessment should take place in the actual sedation setting, with the practitioner's sedation team.

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CHAPTER 12

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## Quality Improvement and Assurance

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### Introduction



The growth in requests for sedation and anesthesia outside of the operating room for children undergoing diagnostic and invasive procedures has been impressive. With this increase has also come increased interest in ensuring these children receive safe, high-quality care, regardless of the location and type of practitioner. Like all other areas of medicine, defining what *safe and high-quality care* means is no small challenge.

### National Clinical Guidelines and Regulatory Mandates



As a result of multiple dental sedation disasters in the 1980s, the risks of pediatric sedation came to light. In an effort to provide a framework for consistently safe pediatric sedation, the American Academy of Pediatrics (AAP) and American Academy of Pediatric Dentistry (AAPD) joined together to produce the first set of pediatric sedation guidelines.<sup>1</sup> Since being published in 1985,<sup>2</sup> the AAP/AAPD guidelines have been updated several times and joined by guidelines from other societies, including the American Society of Anesthesiologists (ASA) and American College of Emergency Physicians (ACEP). While a comprehensive discussion of the various guidelines is beyond the scope of this chapter, a brief overview highlighting the similarities and differences among these guidelines is provided.

## **American Academy of Pediatrics/American Academy of Pediatric Dentistry**

With guidelines first published in 1985 and several subsequent revisions, the latest in 2006, the AAP and AAPD were leaders in recognizing the need for guidelines to help ensure safe sedation practices across practitioners and locations. These documents defined depth of sedation, suitable patient selection, facility requirements, backup services, peri-sedation documentation, monitoring requirements, fasting, and ongoing quality improvement efforts.<sup>1,2</sup> The guidelines highlighted the notion that sedation is a continuum without a clear delineation between levels and that practitioners should be able to rescue patients who move into a deeper level of sedation than intended. In addition, for deep sedation, they recommended that a dedicated person be present to monitor the patient. Additionally, it was suggested that someone in attendance must be certified in Pediatric Advanced Life Support (PALS) and “skilled” in airway management to rescue patients from unanticipated events. The success of these guidelines was evident from the fact that they were incorporated into policies and procedures written at institutions throughout the country as development and expansion of sedation programs occurred during the late 1980s and early 1990s.

## **American Society of Anesthesiologists**

In 2002, the ASA updated the original practice guidelines for sedation and analgesia by non-anesthesiologists.<sup>3</sup> In most respects, the ASA and AAP/AAPD guidelines are very similar with the exception of some nuances of language. One example of this is the recommendation on the use of end-tidal carbon dioxide (ETCO<sub>2</sub>) monitoring. The 2006 guidelines from the AAP/AAPD “encourage” its use, while those from the ASA have recently been amended to recommend its use during procedural sedation.

## **American College of Emergency Physicians**

The American College of Emergency Physicians initially published guidelines on procedural sedation and analgesia in 2005 and updated them in 2014.<sup>4,5</sup> While much of the policy is similar to those by the AAP/AAPD and ASA, there are some important points worth mentioning (Table 12-1). First, ACEP explicitly states that board-certified emergency medicine physicians have core competencies that include cardiovascular resuscitation, advanced

**Table 12-1. Comparison of American College of Emergency Physicians Recommendations With Other Organizations<sup>a</sup>**

	<b>AAP/AAPD</b>	<b>ASA: MDA</b>	<b>ASA: non-MDA</b>	<b>ACEP</b>
<b>Oxygen saturation</b>	Continuous with variable pitch	Continuous with variable pitch	Continuous with variable pitch	When increased risk of hypoxemia
<b>Respiratory rate</b>	Intermittent	Continual	Continuous	Not specified
<b>Heart rate</b>	Continuous	Continuous	Continuous	Consider
<b>Blood pressure</b>	Intermittent	Intermittent	Intermittent	Not specified
<b>ETCO<sub>2</sub></b>	Encouraged	Continual	Consider	No
<b>IV access</b> <b>Moderate</b> <b>Deep</b>	Not specified Yes, or capable	Not addressed	Yes, if sedation given IV. Case dependent otherwise.	Yes, if sedation given IV. Case dependent otherwise.
<b>Fasting</b> <b>Clear liquids</b> <b>Human milk</b> <b>Formula</b> <b>Light solids</b>	2 h 4 h 6 h 6 h	2 h 4 h 6 h 6 h	2 h 4 h 6 h 6 h	Complex guidelines

Abbreviations: AAP, American Academy of Pediatrics; AAPD, American Academy of Pediatric Dentists; ACEP, American College of Emergency Physicians; ASA, American Society of Anesthesiologists; ETCO<sub>2</sub>, end-tidal carbon dioxide; IV, intravenous; MDA, doctor of medicine in anesthesiology.

<sup>a</sup>Continual, repeated regularly and frequently in steady rapid succession; continuous, prolonged without any interruption at any time.

Adapted from: Langan ML, Mallory M, Hertzog J, Lowrie L, Cravero J; Pediatric Sedation Research Consortium. Physiologic monitoring practices during pediatric procedural sedation: a report from the Pediatric Sedation Research Consortium. *Arch Pediatr Adolesc Med*. 2012;166(11):990–998. Copyright ©2012 American Medical Association. All rights reserved.

airway management skills, and provision of sedation of all forms, including for those patients who have achieved general anesthesia. This was added to address any questions about skill sets that different specialties have in terms of credentialing for sedation. A second key difference is recommendations about pre-sedation fasting. The American College of Emergency Physicians recognizes that sedation in the emergency department (ED) performed by emergency medicine physicians is unique compared with other environments. Because a large portion of sedations in the ED are not elective, ACEP developed an algorithm taking into consideration patient risk factors, time since last oral intake, type of last oral intake, and urgency of the procedure to help guide what depth of sedation it feels is safe (Figure 12-1). A third

Figure 12-1

Standard-risk patient <sup>a</sup>					<div>Procedural sedation and analgesia targeted depth and duration<sup>c</sup></div> <div><div>↓</div><div>Increasing potential aspiration risk</div><div>↓</div></div>
Oral intake in the prior 3 hours	Procedural Urgency <sup>b</sup>				
	Emergent Procedure	Urgent Procedure	Semi-Urgent	Non-Urgent	
Nothing	All levels of sedation	All levels of sedation	All levels of sedation	All levels of sedation	
Clear liquids only	All levels of sedation	All levels of sedation	Up to and including brief deep sedation	Up to and including extended moderate sedation	
Light snack	All levels of sedation	Up to and including brief deep sedation	Up to and including dissociative sedation; non-extended moderate sedation	Minimal sedation only	
Heavier snack or meal	All levels of sedation	Up to and including extended moderate sedation	Minimal sedation only	Minimal sedation only	
Higher-risk patient <sup>a</sup>					
Oral intake in the prior 3 hours	Procedural Urgency <sup>b</sup>				
	Emergent Procedure	Urgent Procedure	Semi-Urgent	Non-Urgent	
Nothing	All levels of sedation	All levels of sedation	All levels of sedation	All levels of sedation	
Clear liquids only	All levels of sedation	Up to and including brief deep sedation	Up to and including extended moderate sedation	Minimal sedation only	
Light snack	All levels of sedation	Up to and including dissociative sedation; non-extended moderate sedation	Minimal sedation only	Minimal sedation only	
Heavier snack or meal	All levels of sedation	Up to and including dissociative sedation; non-extended moderate sedation	Minimal sedation only	Minimal sedation only	

Brief: <10 minutes  
Intermediate: 10–20 minutes  
Extended: >20 minutes

Stratification of emergency department procedural sedation

<sup>a</sup> Higher-risk patients are those with one or more of the following present to a degree individually or cumulatively judged clinically important by the treating physician:

- Potential for difficult or prolonged assisted ventilation should an airway complication occur (eg, short neck, small mandible/micrognathia, large tongue, tracheomalacia, laryngomalacia, history of difficult intubation, congenital anomalies of the airway and neck, sleep apnea)
- Conditions predisposing to esophageal reflux (eg, elevated intracranial pressure, esophageal, hiatal hernia, peptic ulcer disease, gastritis, bowel obstruction, ileus, tracheo-esophageal fistula)
- Extremes of age (eg, >70 years or <6 months)
- Severe systemic disease with definite functional limitation (ie, ASA physical status 3 or greater)
- Other clinical findings leading the EP to judge the patient to be at higher than standard risk (eg, altered level of consciousness, frail appearance)

<sup>b</sup> Procedural urgency:

- Emergent (eg, cardioversion for life-threatening dysrhythmia, reduction of markedly angulated fracture or dislocation with soft tissue or vascular compromise, intractable pain or suffering).
- Urgent (eg, care of dirty wounds and lacerations, animal and human bites, abscess incision and drainage, fracture reduction, hip reduction, lumbar puncture for suspected meningitis, arthrocentesis, neuroimaging for trauma)
- Semi-urgent (eg, care of clean wounds and lacerations, shoulder reduction, neuroimaging for new-onset seizure, foreign body removal, sexual assault examination)
- Non-urgent or elective (eg, non-vegetable foreign body in external auditory canal, chronic embedded soft tissue foreign body, ingrown toenail)

**Figure 12-1, continued**

◦ Procedural sedation and analgesia terminology and definitions:

- Minimal sedation (anxiolysis): A drug-induced state during which patients respond normally to verbal commands. Although cognitive function and coordination may be impaired, ventilatory and cardiovascular functions are unaffected.
- Moderate sedation (formerly “conscious sedation”): A drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation. Reflex withdrawal from a painful stimulus is not considered a purposeful response. No interventions are required to maintain a patent airway, and spontaneous ventilation is adequate. Cardiovascular function is usually maintained.
- Dissociative sedation: A trance-like cataleptic state induced by the dissociative agent ketamine characterized by profound analgesia and amnesia, with retention of protective airway reflexes, spontaneous respirations, and cardiopulmonary stability.
- Deep sedation: A drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully following repeated or painful stimulation. The ability to independently maintain ventilatory function may be impaired. Patients may require assistance in maintaining a patent airway and spontaneous ventilation may be inadequate. Cardiovascular function is usually maintained.
- General anesthesia: A drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation. The ability to independently maintain ventilatory function is often impaired. Patients often require assistance in maintaining a patent airway, and positive pressure ventilation may be required because of depressed spontaneous ventilation or drug-induced depression of neuromuscular function. Cardiovascular function may be impaired.

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difference is that ACEP adds a novel type or level of sedation, termed *dissociative sedation*. This distinction was made on the premise that dissociative agents, such as ketamine, have unique properties, not only in terms of risks and benefits but also mechanism of action. As such, members of ACEP who developed the guidelines determined that it warranted its own category. The last major difference concerns recommendations for monitoring. Unlike the AAP/AAPD and ASA documents, which have similar and relatively concrete guidelines on monitoring, ACEP leaves much more to the discretion of the practitioner. The emphasis of ACEP tends to be more guided by the fact that all monitoring devices have limitations and physician observation of the patient is of equal importance. In specific terms of monitoring respiratory status, ACEP guidelines state that “pulse oximetry should be used in patients at increased risk of developing hypoxia.” For capnography, ACEP guidelines state that “capnography may be used as an adjunct to pulse oximetry and clinical assessment to detect hypoventilation and apnea earlier than pulse

oximetry and/or clinical assessment alone in patients undergoing procedural sedation and analgesia in the ED.” In terms of other vital signs, the guidelines instruct to “obtain and document vital signs before, during and after procedural sedation and analgesia.”

## Defining and Measuring Quality of Care

### What to Measure

Although one will easily and quickly agree that quality of care is mandatory for procedural sedation, deciding what to measure is a more complex decision that is frequently open to debate. In broad terms, we can divide quality information into various categories.

1. Business and efficiency
2. Process and patient throughput
3. Sentinel and adverse events
4. Outcome, including clinical and satisfaction measures from parents, patients, and physicians requesting sedation

It should be recognized that some information may fit into more than one category. How much effort is devoted to each will likely depend on who is asking the questions, resources available, and larger goals of the program. For instance, a small rural hospital that does only a few pediatric sedations each year may not focus on business metrics but solely on sentinel and adverse events. A large, freestanding pediatric hospital that has a dedicated sedation service, on the other hand, may have the need and resources to obtain metrics in all of these categories.

Business and efficiency metrics are those that reflect how well the service is running from a financial and operational perspective. While these metrics are not typically thought of in terms of quality, many of the questions asked from a financial and operational perspective are also important from a satisfaction perspective. For example, a common business metric is percent of sedations or cases that start within 5 minutes of the scheduled start time. This is important to the bottom line of the service and facility, as it reflects how well a program is using its workforce and facilities. It is also important

to families and patients; it is one way they define quality care. In a similar light, measuring percentage of cancellations or patients who don't show up for a scheduled procedure is important in that it reflects lost revenue as well as missed opportunities for other patients to have their procedures done. This becomes increasingly important for facilities that have longer waiting time between scheduling and completing a procedure.

Process metrics measure adherence to a specific process while assuming adherence will result in a desired outcome. This type of metric has become popular in health care and is starting to be used as a factor in payment. One government project using process metrics is the Surgical Care Improvement Project (SCIP). One of the many processes for which hospitals collect data for the Centers for Medicare & Medicaid Services (CMS) is SCIP-10, which measures looks at normothermia after general or neuraxial anesthesia. Specifically, it requires that patient have a temperature above 36.0°C at the completion of a procedure to meet the standard.<sup>6</sup> It is assumed that adherence to this measure of keeping patients warm during an anesthetic event will result in lower morbidity and mortality. Critics of these types of data argue that these data do not measure what is important: the actual outcome. Despite their limitations, process measures will likely continue to be heavily used because they have at least 2 significant advantages over actual outcome measures, including easily reproducible definitions of the measured process and relatively low data acquisition costs.

Business or efficiency and process metrics play an important role in a robust quality program and are key to ensure the financial success of the program, especially in a fee-for-service model of payment. As noted previously, the importance of finances tends to grow with the program. Smaller programs may not notice financial losses related to a program; however, larger programs may have a separate budget for procedural-sedation centers with the need to ensure at least financial neutrality. As such, effective billing practices are mandatory to maximize payment within the guidelines of the staffing paradigm. Metrics for these parameters generally include appropriate documentation required for billing, how quickly bills are submitted for payment, the percent collection rate, and the overall bottom line (ie, whether the program covers its own costs).

When looking at outcomes data, it is important to remember that they include clinical (ie, morbidity and mortality) and nonclinical (eg, patient satisfaction) metrics. Sentinel events are often the first type of data to



come to mind as one tracks memorable events. According to The Joint Commission, a sentinel event is “an unexpected occurrence involving death or serious physical or psychological injury or risk thereof.”<sup>7</sup> Tracking sentinel events has been a mainstay of clinical quality programs for some time. Historically, cases that had sentinel events are discussed at weekly or monthly morbidity and mortality meetings at which a group reviews cases and gives input on how individuals or the process could have prevented the event from happening. Given the importance of such reviews, the structure has shifted away from “blaming” and finding “fault,” typically in individuals and their care, toward looking at system issues that allowed the event to occur.

What constitutes a sentinel event depends in some part on the clinical area of practice (eg, hospital, ambulatory care, office-based surgery) and how the institution defines such events, as long as they fit into the broad Joint Commission definition of sentinel event.<sup>8</sup> With that said, a few examples of events that are universally accepted include complications or errors resulting in death, blood transfusion reactions, retained foreign objects, wrong site, and wrong patient procedures. In addition to defining and tracking sentinel events, accredited institutions are required by The Joint Commission to respond “appropriately” to any event that fits the definitions. An appropriate response includes a timely root cause analysis, developing an action plan to reduce risks of similar incidences, and monitoring the effectiveness of such improvements.<sup>8</sup> While sentinel event tracking is important, these are not the only outcome measures worthy of following. Deciding what outcomes to measure will depend on clinical area, areas of targeted improvement, national and professional society guidelines, and participation in multi-institution databanks, to name a few.

## Defining Metrics

On the surface, deciding what metrics to follow seems easy, but this simplicity is quickly replaced with complexity as one realizes that even “clear” end points, like death, can be interpreted differently. For instance, if you are looking at death in relation to sedation administered for magnetic resonance imaging (MRI), you could define it very narrowly as only those patients who died while having sedation or more globally as those who died at any point within a month after sedation. While somewhat extreme, we believe that this demonstrates the potential problems with defining metrics in the clinical arena. A more realistic question concerns whether you count a patient who

dies as an event only if it occurs during the sedation or recovery period or within 24, 48, or 72 hours of the procedure? Additionally, the mortality event or any morbidity must be considered in the context of the patient's comorbid conditions. Mortality is definitely unexpected in an otherwise healthy patient (ASA class 1) but not unexpected in critically ill patients brought for a last-effort procedure (ASA class 5E [E=emergent]).

Definitions become even more complicated as the measured outcome becomes less clear. For example, measuring "respiratory complications" can include the spectrum of oxygen desaturation, airway obstruction, aspiration, and laryngospasm to required post-sedation endotracheal intubation and ventilation in the intensive care unit (ICU). Even defining desaturation can be a challenge. When considering oxygen desaturation, should one use an arbitrary low value of less than 94%, less than 90%, or more than a 10% or 20% decrease from baseline? Does duration of event play a role? How these hurdles are overcome partially depends on how the information will be used. If data are only going to be used internally, an institution has more latitude in tailoring a definition to fit its needs. On the other hand, if an institution wishes to compare its rates of events to others (benchmark), it will have to conform to external definitions, even if those definitions are not exactly what the institution would choose to use.

Even in pediatric sedation, what metrics should be measured and how to define them are not clear-cut. Definitions have been an agreed-on variable, occasionally including a duration, that did or did not happen, eg, oxygen desaturation below 90% for 30 or more seconds. A competing camp makes the argument that these definitions, even when agreed on, are often difficult to track and do not get at the intent of adverse event tracking, which is to track serious events rather than surrogates. Can you really discern 25 versus 35 seconds of hypoxemia in the midst of an event? It is also argued that 10 seconds of oxygen desaturation that returns to baseline may not be an adverse event but a normal part of patient care. This competing camp proposes a shift from a threshold and duration system to intervention-based definitions. For example, when the Pediatric Emergency Care Applied Research Network (PECARN) and Pediatric Emergency Research Canada (PERC) track the incidence of apnea, at least 1 of 5 criteria indicating apnea must occur, including apnea identified by visual confirmation of cessation of ventilation, cyanosis, oxygen desaturation, or loss of ETCO<sub>2</sub> waveform plus an intervention (eg, vigorous tactile stimulation, administration of a reversal

agent, application of bag-valve-mask–assisted ventilation or endotracheal intubation). One from each category must be present to count as an adverse event.<sup>9</sup> The International Sedation Task Force Adverse Event Sedation Reporting Tool is similar in approach but categorizes events (minimal, minor, and sentinel risks), interventions (minimal, minor, moderate, and sentinel), outcomes (minimal, moderate, and sentinel), and overall severity (minimal, minor, moderate, and sentinel).<sup>10</sup> Using the same apnea example, apnea for fewer than 60 seconds is classified as a minor risk, while apnea lasting more than 60 seconds is a sentinel risk. Interventions to address the apneic episode could be minor (eg, airway repositioning), moderate (eg, bag-mask ventilation, placement of a laryngeal mask airway, oral/nasal airway) or sentinel (eg, endotracheal intubation). Outcomes range from no adverse effects (minimal), to unplanned hospitalization or escalation of care (moderate), to death or permanent neurologic deficit (sentinel). The severity rating assigned depends on the most serious option checked in the 3 categories.

While most large organizations advocate measuring events such as death, cardiac arrest, and unplanned hospitalization, beyond a few basic metrics, there are more differences than similarities. Table 12-2 shows adverse events measured by the following 4 prominent organizations that deal with sedation and anesthesia:

1. Pediatric Sedation Research Consortium (PSRC)
2. PECARN/PERC
3. World SIVA International Sedation Task Force (ISTF)
4. Anesthesia Quality Institute (AQI)

As mentioned previously, PECARN/PERC and ISTF have these metrics but also require an intervention, while the PSRC and AQI only require meeting one of these to count as a reportable adverse event. The bold metrics in Table 12-2 represent those that are common to at least 2 of the organizations. While many are common, none of the organizations have an identical list of adverse events, showing again the issues in creating universal metrics to report.

**Table 12-2. Tracked Adverse Sedation or Anesthesia Events by Organization<sup>a</sup>**

<b>PSRC<sup>b</sup></b>	<b>PECARN/PERC<sup>c</sup></b>	<b>International Sedation Task Force<sup>d</sup></b>	<b>AQI<sup>e</sup></b>
<b>Agitation/Delirium</b>	<b>Oxygen desaturation</b>	<b>Vomiting/retching</b>	Significant delay
<b>Airway Obstruction</b>	<b>Apnea</b>	Subclinical respiratory depression	Case canceled
<b>Allergic Reaction</b>	<b>Airway obstruction</b>	<b>Muscle rigidity/myoclonus</b>	Equipment problem
<b>Apnea</b>	<b>Laryngospasm</b>	Hyperventilation	<b>Extended PACU stay</b>
<b>Aspiration</b>	<b>Pulmonary aspiration</b>	<b>Paradoxical response</b>	<b>Unanticipated hospital admission</b>
<b>Cardiac Arrest</b>	<b>Retching/vomiting</b>	<b>Recovery agitation</b>	<b>Unanticipated ICU admission</b>
Coughing	<b>Bradycardia</b>	<b>Prolonged recovery</b>	<b>Death</b>
<b>Death</b>	<b>Hypotension</b>	<b>Oxygen desaturation</b>	<b>Cardiac arrest</b>
<b>Desaturation</b>	<b>Excitatory movements</b>	<b>Apnea (not prolonged)</b>	<b>Anaphylaxis</b>
Emergency Anesthesia Consultation	<b>Paradoxical response to sedation</b>	<b>Airway obstruction</b>	Malignant hyperthermia
<b>Hypothermia</b>	<b>Unpleasant recovery reactions</b>	Failed sedation	Transfusion reaction
Inadequate Sedation	Permanent neurologic changes	<b>Allergic reaction (w/o anaphylaxis)</b>	New stroke
<b>IV-Related Complications</b>	<b>Death</b>	<b>Bradycardia</b>	Visual loss
<b>Laryngospasm</b>	Other	Tachycardia	Medication error
<b>Prolonged Recovery</b>		<b>Hypotension</b>	Incorrect surgical site
Prolonged Sedation		Hypertension	Incorrect patient
Secretions requiring treatment		Seizure	Intraoperative awareness
Stridor		<b>Oxygen desaturation (severe)</b>	Unrecognized difficult airway
Unexpected change in HR or BP >30% from baseline		<b>Apnea, prolonged</b>	Unplanned reintubation

**Table 12-2. Tracked Adverse Sedation or Anesthesia Events by Organization<sup>a</sup>, continued**

PSRC <sup>b</sup>	PECARN/PERC <sup>c</sup>	International Sedation Task Force <sup>d</sup>	AQI <sup>e</sup>
Unexpected bag-mask ventilation		Cardiovascular collapse/shock	Dental trauma
Unintended deep level of sedation		<b>Cardiac arrest/absent pulse</b>	<b>Perioperative aspiration</b>
<b>Unplanned admission or increase in level of care</b>		<b>Death</b>	Pneumothorax
<b>Unplanned intubation</b>		<b>Unplanned hospitalization/escalation of care</b>	<b>Vascular access complication</b>
Unplanned use of reversal agents		<b>Unplanned intubation</b>	Infection after regional anesthesia
<b>Vomiting</b>		<b>Other</b>	Local anesthesia toxicity
Wheezing			Peripheral neurologic deficit
Other			<b>PONV (any)</b>
			<b>Hypothermia (PACU)</b>
			Hypotension (PACU)
			Inadequate pain control

Abbreviations: AQI, Anesthesia Quality Institute; BP, blood pressure; HR, heart rate; ICU, intensive care unit; IV, intravenous; PACU, postanesthesia care unit; PECARN, Pediatric Emergency Care Applied Research Network; PERC, Pediatric Emergency Research Canada; PONV, postoperative nausea and vomiting; PSRC, Pediatric Sedation Research Consortium.

<sup>a</sup>Note: The **bold** metrics represent those that are common to at least 2 of the organizations.

<sup>b</sup>Cravero JP, Blike GT, Beach M, et al. Incidence and nature of adverse events during pediatric sedation/anesthesia for procedures outside the operating room: report from the Pediatric Sedation Research Consortium. *Pediatrics*. 2006;118(3):1087–1096.

<sup>c</sup>Bhatt M, Kennedy RM, Osmond MH, et al. Consensus-based recommendations for standardizing terminology and reporting adverse events for emergency department procedural sedation and analgesia in children. *Ann Emerg Med*. 2009;53(4):426–435.

<sup>d</sup>Mason KP, Green SM, Piacevoli Q; International Sedation Task Force. Adverse event reporting tool to standardize the reporting and tracking of adverse events during procedural sedation: a consensus document from the World SIVA International Sedation Task Force. *Br J Anaesth*. 2012;108(1):13–20.

<sup>e</sup>Anesthesia Quality Institute. <http://www.aqihq.org>. Accessed May 26, 2015.


## How to Measure and Acquire Information

When discussing how to collect information on quality, most discussions focus on 1 of 2 ways: *self-reporting* or *record review*. While these methods of acquiring information are useful and common, they are not the only ways of acquiring data on quality. In addition, it is useful to explore active surveillance and trigger tool methodology as useful alternatives or adjuncts to the process.

### *Self-reporting*

Self-reporting is, by definition, a process in which a person involved directly or indirectly recognizes and reports some variation from the expected process. Data generated by self-reporting are a common method for acquiring quality metrics in most traditional quality improvement programs, as it is assumed to be relatively inexpensive, simple to obtain, and generally accurate. Collection tools can take many formats, from paper incident collection forms (Figure 12-2) to elaborate electronic collection forms. Self-reported data are typically collected in 2 ways: only on cases when a variance or event occurs, or for all cases regardless of whether a variance or event occurs. For instance, if a department chooses to track cardiac arrests during sedation for MRI, it can choose to generate an event form only when a patient having an MRI also has cardiac arrest, or it can generate a form for all patients having sedation for an MRI regardless of any events taking place, with a practitioner actively reporting presence or absence of cardiac arrest. Systems that rely only on positive responses are much less burdensome on practitioners but may be less accurate in terms of giving an incidence of tracked events, as the denominator of total cases is often harder to firmly quantify. Additionally, if practitioners must remember to fill out a form only in the cases of a positive event, they may be more likely to forget, even for significant events, and thus not capture data as intended. However, asking practitioners to report on all cases regardless of whether an event occurred is not without its limitations. Because tracked events are often low occurrence, the default becomes “no” and positive events can also be missed. However, this method will provide a more reliable incidence rate in that one will have a total number of cases (denominator), assuming that a form is completed for each case performed.

Figure 12-2



**NATIONWIDE CHILDREN'S**  
*When your child needs a hospital, everything matters.™*

**UNUSUAL PERIANESTHETIC EVENTS**  
Department of Anesthesiology

Surg Date: / /

Hosp# \_\_\_\_\_

DATE OF BIRTH / /

Did an UPE Occur?  
IN O.R.: ☐ Y ☐ N  
IN PACU: ☐ Y ☐ N

**RESPIRATORY**  
OR RR  
☐ ☐ Laryngospasm  
☐ ☐ Bronchospasm  
☐ ☐ O<sub>2</sub> Desaturation (SaO<sub>2</sub> < 90%)  
☐ ☐ Significant desaturation from abnormal baseline SaO<sub>2</sub> (< 90%)  
☐ ☐ Hypercarbia (PaCO<sub>2</sub> > 60mmHg)  
☐ ☐ Emesis with unprotected airway  
☐ ☐ Emesis with protected airway  
☐ ☐ Aspiration (known or probable)  
☐ ☐ Difficult intubation  
☐ ☐ Difficult for anesthetist  
☐ ☐ Difficult for anesthesiologist  
☐ ☐ Failed intubation  
☐ ☐ Awake intubation  
☐ ☐ F/O intubation  
☐ ☐ Unplanned extubation, by:  
☐ Surgeon ☐ Anes. ☐ Pt.  
☐ ☐ Reintubation required  
☐ ☐ Pneumothorax  
☐ ☐ Pulmonary edema  
☐ ☐ Other \_\_\_\_\_  
 Explain: \_\_\_\_\_

**CARDIOVASCULAR**  
OR RR  
☐ ☐ Hypotension requiring treatment  
☐ ☐ Lighten anesthetic  
☐ ☐ Fluids liberalized  
☐ ☐ Vasopressor (s)  
☐ ☐ Treat bradycardia  
☐ ☐ Other \_\_\_\_\_  
☐ ☐ Hypertension requiring treatment  
☐ ☐ Bradycardia requiring treatment  
☐ ☐ Ventricular ectopy  
☐ ☐ Other dysrhythmia  
☐ ☐ Cardiac arrest  
☐ ☐ Air embolism  
☐ ☐ Other \_\_\_\_\_

**METABOLIC**  
OR RR  
☐ ☐ Hyperthermia >101°F (38.3°C)  
☐ ☐ Hypothermia < 95°F (35°C)  
☐ ☐ Acidosis (- base deficit > 6)  
☐ ☐ Alkalosis (+ base excess > 6)  
☐ ☐ Electrolyte imbalance  
☐ ☐ Explain: \_\_\_\_\_  
☐ ☐ Other \_\_\_\_\_

**DRUGS**  
OR RR  
☐ ☐ Wrong drug  
☐ ☐ Wrong dose  
☐ ☐ Unexpected response  
☐ ☐ Prolonged non-depolar block  
☐ ☐ Prolonged succinylch block  
☐ ☐ Masseter spasm  
☐ ☐ Malignant hyperthermia  
☐ ☐ Anaphylaxis 2° to: \_\_\_\_\_  
 with: ☐ airway edema ☐ rash  
☐ hypotension ☐ bronchospasm  
☐ ☐ Other \_\_\_\_\_

**NEURO**  
OR RR  
☐ ☐ Seizures  
☐ ☐ Abnormal neuro monitoring  
☐ ☐ Other \_\_\_\_\_

**TRAUMA**  
OR RR  
☐ ☐ Dental, lips, mouth, oropharynx  
☐ ☐ Eyes (corneal abrasion, etc.)  
☐ ☐ Extremities, torso  
☐ ☐ Burn (electrical, thermal, chemical)  
☐ ☐ Position related injury  
☐ ☐ Patient induced trauma  
☐ ☐ Explain: \_\_\_\_\_  
☐ ☐ Other \_\_\_\_\_

**REGIONAL TECHNIQUE**  
OR RR  
☐ ☐ Attempted, not achieved  
☐ ☐ CSF unintentionally violated  
☐ ☐ Intravascular injection  
☐ ☐ Inadequate block  
☐ ☐ Adverse reaction to local anesthetic  
☐ ☐ Other \_\_\_\_\_

**EQUIPMENT MALFUNCTION**  
OR RR  
☐ ☐ Anesthesia machine or circuit  
☐ ☐ Other \_\_\_\_\_  
☐ ☐ Explain: \_\_\_\_\_  
☐ ☐ Monitor failure (significant)  
☐ ☐ Explain: \_\_\_\_\_

**DEATH**  
OR RR  
☐ ☐

**OTHER MORBIDITY**  
OR RR  
☐ ☐ Case aborted in OR  
☐ ☐ Return to OR  
☐ ☐ Other \_\_\_\_\_

**PACU ADDITIONAL**  
☐ Apnea  
☐ Croup requiring Rx  
☐ Delirium requiring Rx  
☐ Prolonged stay (>2 hrs)  
☐ Pain  
☐ Medical mgmt.  
☐ Pt. transport  
☐ Pt. placement  
☐ Unplanned Admission  
☐ Hospital  
☐ NICU/PICU  
☐ Access for QA  
 Notes: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
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 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
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Adverse event reporting sheet for operating room procedures

From the Department of Anesthesiology and Pain Medicine, Nationwide Children's Hospital, Columbus, OH.

## Record Review

Record reviews are, as the name implies, an active review of the medical record as care is ongoing or, more commonly, after the episode of care is complete. Typically, a nurse or physician, looking for evidence of adverse events, reviews the documentation. The advantage of this method is having

an individual review the entire medical record and look for any evidence of adverse events without bias, as the actual practitioner is not involved. The major drawback to this method is that it is resource intense, as a person has to review each medical record in its entirety. An additional limitation to this method is that information available for review is limited to what is documented in the medical record with little ability to ask more questions. Nonetheless, this is still considered the gold standard for detection of adverse events.

### *Active Surveillance*

Active surveillance is the process of reviewing medical care as it is occurring, looking for obvious adverse events that have occurred and are being treated or nonroutine events that may lead to unintended events, even if they may not otherwise be classified as adverse. Oken et al<sup>11</sup> describe an example of active surveillance where, at the conclusion of an anesthetic encounter, practitioners were asked a standardized set of open-ended questions meant to identify any nonroutine events. Subsequent questions were then asked based on responses to clarify or investigate further anything that had been found. Other examples of active surveillance would be a nurse reviewing each patient in the ICU with a central venous catheter looking at the duration of catheter placement and evidence of bacteremia and reviewing the continued need with the medical team.

### *Trigger Tool Methodology*

The trigger tool methodology, originally developed in 1974,<sup>12</sup> was brought into the mainstream by the Institute for Healthcare Improvement (IHI) in 1999 as a method of tracking progress on its adverse drug event initiative.<sup>13</sup> The tool is a retrospective review of a predetermined number of random charts or encounters (10–20) that is performed at predetermined intervals (typically once during the first half and once during the second half of each year) looking for specific triggers or clues that an adverse event may have occurred. When a trigger is found, it prompts a further review to determine if an actual adverse event occurred. If it is determined that an adverse event occurred, its severity is graded on a defined scale. The number of adverse events can then be used to estimate a rate based on the occurrence of such events and tracked over time. This is merely a tracking tool without any sort of intervention to address found adverse events; therefore, it is unlikely that there will be any real change or reduction in the rate of events over time.



Table 12-3. Surgical Module Trigger Tool

Trigger	Description
S1	Return to surgery
S2	Change in procedure
S3	Admission to ICU postoperatively
S4	Intubation, reintubation in PACU
S5	X-ray intraoperative or in PACU
S6	Intraoperative or postoperative death
S7	Mechanical ventilation >24 h postoperatively
S8	Intraoperative epinephrine, norepinephrine, naloxone, or flumazenil administration
S9	Postoperative troponin >1.5 ng/mL
S10	Injury, repair, or removal of organ
S11	Any operative complication

Abbreviations: ICU, intensive care unit; PACU, postanesthesia care unit.

Adapted from: Griffin FA, Resar RK. *IHI Global Trigger Tool for Measuring Adverse Events*. 2nd ed. IHI Innovation Series white paper. Cambridge, MA: Institute for Healthcare Improvements; 2009. <http://www.ihl.org/resources/Pages/IHIWhitePapers/IHIGlobalTriggerToolWhitePaper.aspx>. Accessed May 8, 2015.

While the original intent of the trigger tool methodology was to track adverse drug events, it has been expanded to include aspects of care in most parts of a hospital setting.<sup>13</sup> While there is little specific to pediatric sedation and adverse events in the expansion, triggers from the surgical module (Table 12-3) could be used, adapted, and expanded for the sedation arena. For example, admission to the ICU after procedure, intraoperative or postoperative death, and use of epinephrine, naloxone, or flumazenil could be used. Possible additions to the list include laryngeal mask airway/endo-tracheal tube/oral airway placement, conversion to general anesthesia, and oxygen saturation below 90%.

Because this methodology is meant to be a way of tracking events within an institution and not a means for comparing one institution's rate of events to another, it allows flexibility in designing triggers and definitions around them.

## Comparing the Tools

Regardless of the institution and size of the sedation program, significant thought should be given to the selection of collection tools that will give the best chance of detecting issues in sedation delivery. For most programs, self-reporting of adverse events has been the method used for years, as it is relatively simple and inexpensive to collect and is thought to provide accurate and complete information. However, it has been known for many years that its sensitivity is relatively low. In 1977, Bennett and Lipman compared the incidence of adverse drug reactions detected from an active surveillance program with a voluntary reporting system.<sup>14</sup> They found an incidence of 7.2% in the active surveillance group compared with 0.08% in the voluntary reporting group. Classen et al found a similar discrepancy when they compared the use of trigger tool methodology to voluntary reporting for adverse drug events.<sup>15</sup> There were 731 adverse events detected by trigger tool methodology but only 9 by voluntary reporting.

Given the shortfall in sensitivity of the voluntary reporting of adverse drug reactions compared with other methods, it is prudent to ask if similar discrepancies exist with other adverse events. Sharek et al compared trigger tool methodology adapted for the neonatal ICU with traditional voluntary reporting of adverse events.<sup>16</sup> They found that only 8% of adverse events detected by trigger tools were reported voluntarily, while the trigger tools missed only 6.1% of adverse events reported voluntarily. Similar discrepancies were seen when investigators looked in the pediatric ICU<sup>17</sup> and perioperative areas.<sup>11</sup> Recognizing that no adverse event tracking or detection tool is perfect, deciding which to use will likely depend on the resources and goals of those asking the questions. There is no doubt that each method can be leveraged to give information, so long as the limitations associated with the collection tools are taken into account when using that information. However, it is likely that the “best” data will come from using more than one detection method.

## Satisfaction Surveys

To *survey* is “to query (someone) in order to collect data for the analysis of some aspect of a group or area.”<sup>18</sup> In medicine, surveys are used for all kinds of information gathering, but most often, they are used to collect data on perception of service. While patients are the most common focus of surveys, other key customers are also important and can be queried as well.

For instance, in sedation, we may be interested in the level of service we are providing to the ordering practitioners in terms of ease of scheduling, time from order to procedure, and reliability and timeliness of procedural reports or results. Furthermore, we may also be interested in our efficacy in providing sedation as judged by the practitioners performing the procedure or interpreting scans and images.

For years, people in businesses outside of medicine have focused on customer satisfaction in an effort to distinguish themselves from competitors and drive more customers to their doors. Medicine has been slow to embrace this concept, but this is rapidly changing. Patient satisfaction in medicine faces challenges not seen in other businesses. For example, in the hotel industry, customers are typically happy (and give a good rating on a survey) when their room is clean, they have good interactions with hotel staff, and they feel the price quoted before staying was fair and didn't change. Medicine has historically played by different rules. For instance, "good care" doesn't always equate to the desired outcome, it is often difficult to predict how much services will cost, and even the most patient-centered facilities often don't favorably compare to even mid-range service hotels.

Government and commercial payers are leading the effort to improve quality care, and patient satisfaction is a large component of how they are defining *quality*. For example, the CMS established its Hospital Value-based Purchasing Program as part of the Patient Protection and Affordable Care Act of 2010, which rates hospitals on clinical care and patient experience and satisfaction. The patient experience component, the Hospital Consumer Assessment of Healthcare Providers and Systems, is collected by a survey asking former inpatients 27 questions about their hospital stay. Questions pertain to communication, responsiveness of staff, cleanliness, noise level, pain management, overall rating of hospital, and direct questions about their medical issues. Hospitals providing care to these patients see a portion of payments for CMS services tied to these metrics (2% by 2017).<sup>19</sup> Government payers are not the only ones expecting improved quality; for instance, several commercial payers anticipate changing their payment structures to include a portion based on quality.<sup>20</sup>

Few dispute that patient satisfaction is important and meaningful. What is much more difficult is to measure it in a way that takes into consideration unique aspects of health care that are not seen in other service industries.

Regardless of these limitations, it is likely that measuring and using patient satisfaction scores will be around for the foreseeable future. As such, those in health care can ignore these data, hoping for the best, or work to learn something despite the limitations.

## Benchmarking

Once quality data are acquired and reviewed, it is common to wonder how an individual or institution is doing compared with its peers. Benchmarking is a point of reference from which measurements may be made, including comparisons of data against a reference set of data. For example, your institution decides to use self-reporting to track the incidence of laryngospasm during sedation and finds an incidence of 1.4%. As a single number, it is difficult to know if this rate is good or represents an opportunity for improvement. On the other hand, a search of the literature reveals that when compared with data presented by Cravero et al from the PSRC, your rate is much higher than the reported rate of 0.04% (4.3:10,000).<sup>21</sup>

Benchmarking can be an extremely useful tool for a quality program when employed appropriately and when some limitations are noted. First, one must make sure that comparisons are accurate. In the laryngospasm example, if we were not comparing a similar population, it would not be nearly as useful. Likewise, if our definition of the metric, laryngospasm, were not the same, it would be hard to make any conclusions. In addition, merely comparing one's data against a reference will likely not result in improvements without additional intervention.

### *National and International Data Registries*

Two of the earliest registries to look at adverse events in anesthesia, including sedation, were the ASA Anesthesia Closed Claims Project and the Pediatric Perioperative Cardiac Arrest (POCA) Registry. The ASA Anesthesia Closed Claims Project includes files from legal claims that have been closed (ie, settled, dismissed, or verdict rendered). While useful in tracking those cases that lead to a legal pursuit of a remedy, it lacks insight into those that do not. The POCA Registry is a database of self-reported cardiac arrest occurring in pediatric patients during anesthesia, including sedation, or recovery. It is currently closed to new submissions, but over the years it has given insight into risks of cardiac arrests. The major drawback of POCA is

that it relies on self-reporting. However, neither of these databases gives an incidence of events because they do not have a denominator of cases.

Over the years, many research projects have attempted to determine how safe sedation is and what the incidence of various adverse events is. Even the most rigorous studies have issues with definitions described earlier, but perhaps the single largest limitation is the relatively low number of patients enrolled. One recent study by Vespasiano et al<sup>22</sup> looked at the incidence of adverse events associated with propofol given by a pediatric intensive care–run sedation service. By most standards, the authors' enrollment of 7,304 patients was impressive. They reported zero cardiac arrests. However, can we extrapolate to larger numbers and conclude that the incidence of cardiac arrest is truly zero? Or are larger volumes needed to accurately delineate a true incidence?

Several organizations that have formed focus solely on sedation (PSRC, ISTF) or include sedation as part of their collected data (AQI) for the purpose of compiling larger numbers of encounters and standardizing definitions of adverse events, and thus improving the chance of determining a meaningful incidence of each event.

## Process Improvement

Having selected metrics for monitoring and benchmarking, organizations can use these data to search for opportunities for improvement. While some issues, such as those resulting in a sentinel event, will be obvious, others will be more subtle. In their landmark report, *Crossing the Quality Chasm*, the Institute of Medicine (IOM) defined health care quality in 6 dimensions.<sup>23</sup> These dimensions of quality can provide a useful guide as programs evaluate their own performance benchmark with similar organizations. The 6 dimensions of quality are

1. *Safe*: Patient safety is of paramount importance. Policies and procedures for pediatric sedation should be designed for optimum patient safety.
2. *Effective*: Clinical practices and guidelines in a sedation service should be evidence based. The practice of pediatric sedation is evolving due to regulatory constraints, medication availability, and development of new techniques. As organizations adopt new procedures, they should insure that these recommendations are based on evidence when available.

3. *Patient centered*: Patient care should be based in empathy, compassion, and responsiveness to patient needs. Pediatric sedation for diagnostic or therapeutic procedures can be a frightening experience for patients and families. Practitioners should be mindful of patient and family preferences and processes should be designed to maximize these interactions. Survey tools can be used to assess this dimension.
4. *Timely*: Pediatric sedation services should be designed to minimize delays in diagnostic and therapeutic procedures. Common sources of delay include availability of physician and support staff. Timeliness of care can be a major issue for sedation services. These problems are process based.
5. *Efficient*: Efficiency is also related to timeliness and can be addressed through process improvement. As organizations attempt to minimize waste and maximize efficiency, patient safety must be maintained.
6. *Equitable*: The IOM states that the delivery of high-quality care should not be influenced by socioeconomic status, gender, race, or geographic location. Pediatric sedation service practitioners should monitor and screen their practice to ensure that these factors are not an issue.

The dimensions of quality give organizations a framework to use when analyzing data to recognize opportunities for improvement. Sedation services can choose metrics to follow for each of the dimensions. Once problematic areas are identified, a structured approach to process improvement can be implemented. Quality improvement science offers several potential approaches, including the IHI methodology, lean process management, and Six Sigma.<sup>24</sup> A complete review of each of these methodologies is beyond the scope of this chapter; however, we will present an overview of a model for improvement that can be used for most process improvement projects.

## Process Improvement: An Example

For illustrative purposes, suppose that our pediatric sedation service has recognized case backlog as an opportunity for improvement. The growing volume has resulted in an increase in wait time for the next-available sedation appointment to 60 days. Clearly, this is an issue with timeliness of care and likely efficiency as well, both of which are recognized dimensions of quality by the IOM.

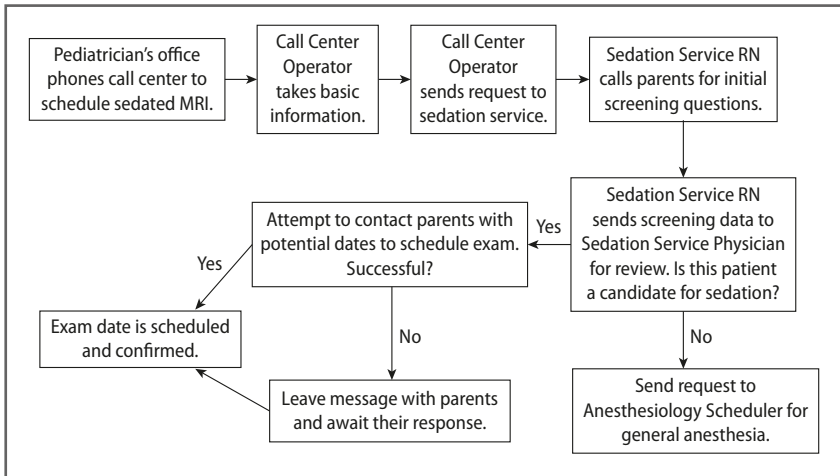
### *Team Building*

The first, and arguably most important, step when initiating a quality improvement program is the formation of a multidisciplinary team. Many problems encountered in the health care environment are complex. In the realm of sedation, it is not uncommon for several different departments to have parallel processes for the same procedure. For example, the departments of pediatrics, radiology, and anesthesiology may each have a different process that needs to occur to schedule a procedure for a sedated child. Like the game *Jenga*, unilaterally changing one process may negatively affect another, causing the system to fail. It is not surprising that, in this setting, teams have been shown to outperform individuals.<sup>25</sup> Selecting appropriate members for the process improvement team can be challenging. Having recognized an opportunity for improvement, leaders can examine existing processes and select team members for involvement. While it is important to have content experts on the team, it is also important to select members that have the ability to collaborate with and the respect of the different departments involved.<sup>26</sup> Once the initial team is selected, there are a number of steps that can be taken to improve the likelihood of success, starting with the creation of a team charter. Forming a team charter is important because it defines the mission of the team, identifies members, and gives structure to the process. As the project matures, the charter can serve as a reference for the team.

### *Setting Goals and Aims*

The first task for the team is to determine its goal; this is frequently communicated via an aim statement. The best aim statements can be described using the SMART acronym (specific, measurable, achievable, relevant, timed). In our example, the team may decide on the following aim for its quality improvement project: By December 1, we will decrease the average wait time for the next-available appointment for sedated MRI from a baseline of 60 days to 30 days in children requiring routine MRI of the brain with sedation.

The aim is specific (children scheduled for routine MRI of brain), measurable (wait time for next-available appointment), achievable (50% reduction), relevant (wait times have been identified as a measure of timeliness of care), and timed (goal is by December 1). Having identified the problem, formed

**Figure 12-3**

Process map for scheduling magnetic resonance imaging with sedation

the team, and determined a goal, the quality improvement team can now proceed with mapping the relevant process.

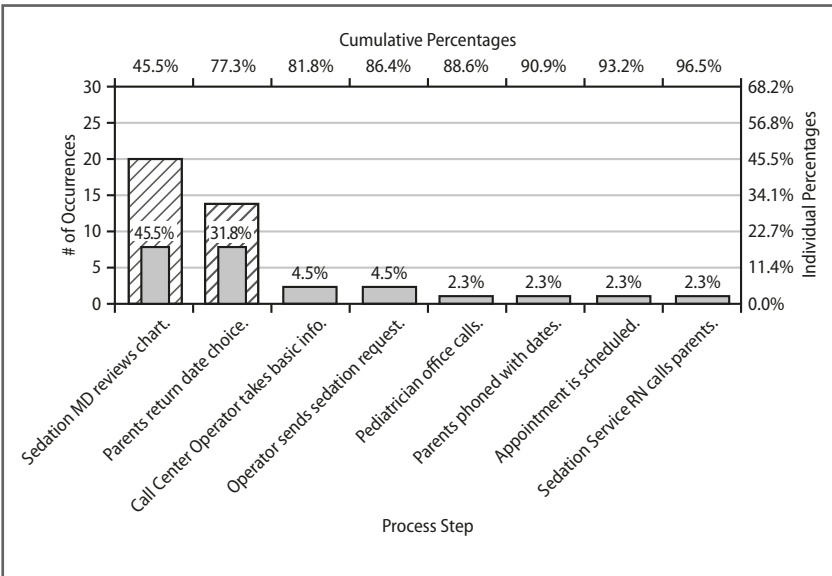
### *Defining Processes*

Health care work processes can be evaluated and improved using the same techniques that are applied to industries around the world.<sup>27</sup> As an initial step, team leaders meet and compose a high-level process map to stimulate discussion. Once team members, who should be very familiar with the process, agree that the high-level map is accurate, more detail can be added. It is important that the process map is correct and of sufficient detail to help the team identify which steps in the process can be improved. Figure 12-3 illustrates an example process map for scheduling MRIs with sedation.

Once the process map is completed, team members can use a variety of techniques to decide which steps are most likely responsible for poor performance. Brainstorming allows each individual team member to share his or her insight as to which process steps are viewed as the most problematic. Team leaders can then collate this input and determine which process steps have the most “votes.” These data can be graphically depicted as a bar chart. It will frequently be the case that most of the problems arise from only a few process steps. This is known as the Pareto principle, which states that 80% of problems can be attributed to 20% of the process steps.<sup>28</sup> Figure 12-4



Figure 12-4



Pareto principle chart

illustrates an example Pareto principle chart designed by the process improvement team working on the backlog of cases for a pediatric sedation center. In addition to Pareto charts, other tools, such as cause-and-effect (fish bone) diagrams and rating scales, may be beneficial as teams seek to identify which process steps are most in need of modification.<sup>29</sup>

### Possible Solutions

In our example, a problem has been identified, a multidisciplinary team established, an aim statement created, a process map agreed on, and the most problematic process steps identified. According to our Pareto chart, the process steps thought to be most problematic are physician chart review (for appropriateness of scheduling as sedation) and contacting parents to schedule an appointment. Taken together, these 2 steps are thought to account for nearly 80% of the delay. Having this information in hand, the team can now turn its attention to possible solutions. Wisely chosen team members can now offer potential solutions to the problems identified. Once there is agreement on which solutions the team feels are feasible, the new procedure can be evaluated. It is recommended that a small, incremental approach be taken at this

point. Again, hospital processes are complex, and adjustment to the process can result in unintended consequences. One popular approach is to initiate small trials of change using the acronym PDSA (*plan, do, study, act*).<sup>30</sup>

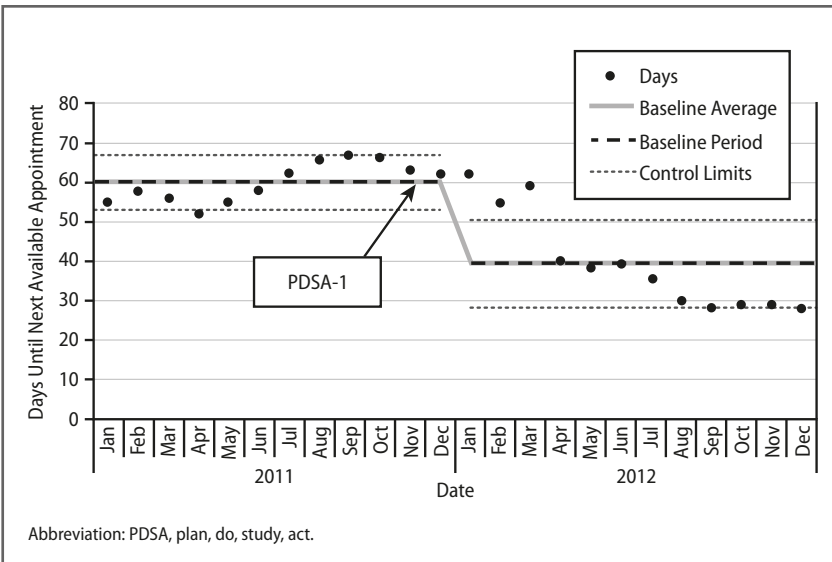
Plan, do, study, act cycles are popular because process improvement teams can use them to test process improvements in a controlled manner and make adjustments before final process and policy changes are implemented. For example, our process improvement team may wish to try a new process in which sedation service nurses contact specific physicians for case review, rather than leaving the request in a general mailbox. The team would likely work with a few select physicians who it feels would be willing to make the change and write the new process. The team may predict that the new process would decrease the time for review from the current baseline of 72 hours to 24 hours. After running the trial, the team notes that the improvement was actually only 48 hours. The team can now evaluate if any further changes to the process would help it meet expectations. Once the team feels that the maximum benefit has been achieved, it can initiate a larger trial with several physicians and measure the effect on overall number of days until next appointment. Similarly, the other process steps can be changed by the team and the effects of small trials measured.

### *Measuring Change*

A fundamental question in quality improvement work is, how do we know that we have made a significant change in the process? To make this assessment, statistical process control (SPC) charts are commonly used. Control charts plot data over time and graphically display control limits. Control limits are mathematically derived boundaries, the limits of which define the upper and lower expectations for performance from a given process.<sup>31</sup>

Although the statistical calculations necessary are beyond the scope of this chapter, a few introductory points can be made. Using SPC charts, one can quickly determine if variation between data points is due to normal variation of the process or some externally applied factor. Common cause variation occurs as a result of normal process fluctuations. These data points are found within the control limits. In contrast, data points found outside of the control limits represent special cause variation. Special cause occurs when some change is introduced to the process.<sup>32</sup> Figure 12-5 represents an SPC control chart depicting days until next available appointment for our example project.

Figure 12-5



Sample statistical process control chart depicting days until next-available appointment

In the first one-third of the chart, common cause variation is depicted. It is important that managers and process improvement teams identify common cause variation so they do not overreact to changes seen in this range. This can lead to process tampering and wasted resources.<sup>33</sup> The data points are within the control limits and any variation noted is a result of the given process. The chart is annotated with PDSA trials, and it is clear that the trials resulted in special cause variation. The process improvement team now has statistical evidence that its intervention resulted in a positive change. The SPC chart can be maintained throughout the life of the project with annotations made for each PDSA cycle. Using this tool, the team can analyze the effects of its interventions and determine if the interventions resulted in significant change. Tests of change that are successful can then be expanded and added as new processes and policies. This method of process improvement has been highly successful in manufacturing and is being increasingly applied to sophisticated health care processes.

## Ensuring Quality in Clinical Care

Adequacy of training for those providing sedation is a safety topic that garners much attention from interested parties, including specialty societies and The Joint Commission. What each defines as needed or required training varies, but it appears the overall goal of requirements, such as PALS certification and formal didactic education, is to have knowledge and experience in recognition and treatment of critical events that can occur during sedation. Residency and fellowship training and board certification in specialties that routinely provide sedation are other markers for experience and ability to recognize and treat these events. However, even those practitioners who take care of the most critical patients rarely see critical events when sedating children, as the incidence of these critical events is low. The PSRC, a multidisciplinary group of practitioners performing pediatric procedural sedation, has shown an overall incidence of serious adverse events to be 9.26 of 10,000 cases.<sup>34</sup> So the question becomes how individuals should initially learn and then maintain skills dealing with low-incidence, high-acuity critical events. For many, simulation has been at least part of the answer.

Medical simulation was first introduced in the 1960s but did not become popular until the late 1980s and early 1990s as technologic advances made its use more common.<sup>35</sup> Simulation can take many forms, from simple case scenarios to high-fidelity simulation with lifelike mannequins that respond to simulated therapeutic interventions. Each type has advantages and disadvantages, but overall they allow knowledge acquisition and opportunities to practice taking care of patients experiencing these low-incidence events in a controlled, safe environment, rather than being faced with it during routine care of a real patient. In addition to individual training, simulation allows groups or teams to work at replicating the intricacies of real-life events, which can expose which systems and processes work well and which need addressing.

Clearly, simulation is not without its detractors; it is relatively expensive and time consuming. So does it make a difference? Shaviv et al looked at the effect of simulation-based training on non-anesthesiologists providing pediatric sedation. Using a 9-criteria sedation safety tool, which evaluated

3 distinct portions of the sedation (pre-evaluation, sedation, and recovery), the authors showed that physicians with simulation training performed better than those without.<sup>36</sup>

As discussed, crisis management often involves personnel who may not routinely work together and occurs in nonfamiliar areas, both of which present their own set of challenges. Simulation is thought to be a useful tool in identifying potential issues in care as well as a way of testing changes thought to improve perceived vulnerabilities. For example, there is a new remote sedation room that has opened, and the protocol for emergencies says that when a code occurs, a call is placed to a predetermined number to activate the code team. No one realized that the new room wasn't assigned a room identifier or number. Recognition of this became apparent during a code simulation prior to the first patient receiving care in the room. Had that not been the case, it is likely that no one would have noticed until a real code occurred. This error may have made a difference in the outcome of the patient. Anecdotal stories such as this one make great arguments for the use of simulation, but is there evidence to support its use? Blike et al used a standardized pediatric simulation patient having a hypoxic event to test the ability of different settings (ED and radiology) to rescue a simulated patient, then compared the response to the same scenario in the operating room, which is thought to be the gold standard.<sup>37</sup> The study showed the time to respond in the ED and radiology to be longer than in the operating room, but as or more importantly, it identified many latent system failures, many of which were thought to contribute to these delays or could contribute during future events. While simulation cannot replace experience in dealing with actual patients, its benefits from a quality and safety perspective, at individual and system levels, appear promising and unlikely to fall out of favor any time soon.

## Summary

Providing consistent, safe, high-quality care for pediatric patients needing sedation is of the utmost importance. Actually defining what that means and how it works in practice is much more difficult. This chapter laid the foundation for developing a successful quality program for pediatric sedation services by reviewing national guidelines as well as highlighting the

issues one faces when defining and measuring quality metrics. A common pitfall is focusing too heavily on obtaining data rather than using it to identify opportunities for improvement. In the second part of the chapter, we discussed process improvement, using the collected quality information to look at opportunities for improvement. Included in this discussion was a model for how to go about implementing process improvement and tracking its effectiveness.

Lastly, we briefly discussed ensuring quality in clinical care. There is no doubt that defining and tracking metrics, then using the information to target process improvement, is part of ensuring quality care. However, you may find that there are areas of opportunity that require acquiring new skills or refreshing old ones. This section discussed some opportunities to address this but primarily focused on simulation and its unique abilities to help practitioners practice critical events in a safe environment without the risk of hurting actual patients. Throughout the chapter, we hope you have recognized opportunities in your own practice to use the information presented to make changes that ultimately improve the quality of the sedation experience for your patients.

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# Procedural Sedation for Infants, Children, and Adolescents

American Academy of Pediatrics  
Section on Anesthesiology and Pain Medicine

## EDITORS

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Joseph P. Cravero, MD, FAAP

Invasive and noninvasive procedures are a common and necessary component in the management of infants, children, and adolescents with acute and chronic diseases. As technology continues to expand, there are an increasing number of techniques that require procedural sedation outside of the operating room.

Authored by experts in a variety of specialties, *Procedural Sedation for Infants, Children, and Adolescents* is a comprehensive guide for the initial design and implementation of a procedural sedation program and a tool to educate pediatric health care professionals on medications used for sedation, associated adverse events, and treatment of these adverse events.

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